PROCEEDINGS OF THE 44TH ANNUAL SOUTHERN AFRICAN COMPUTER LECTURERS ASSOCIATION 2015 (SACLA 2015)

"Renewing ICT teaching and learning:
Building on the past to create new energies"

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REFEREE PROCEDURE

The annual conference of the Southern African Computer Lecturers Association (SACLA) presents lecturers in tertiary departments of Computer Science and Information Systems with an opportunity to share experiences of teaching from undergraduate to doctoral levels. The theme of SACLA 2015 is 'Renewing ICT teaching and learning: building on the past to create new energies'.

The research papers included in the PROCEEDINGS OF THE 44th ANNUAL SOUTHERN AFRICAN COMPUTER LECTURERS ASSOCIATION CONFERENCE (SACLA 2015) were each double-blind peer reviewed by at least two members of the programme committee. The program committee consisted of both local and international experts in the fields of computer science and information systems education, and having expertise and interest in subjects relevant to the theme of the conference.

All papers were initially screened by the programme chairs for fit to the SACLA conference. Papers were then sent for peer review. A total of 61 academics from 14 local and international institutions constituted the programme committee and reviewed papers for the conference. .

The review process followed the double-blind peer review model. Every paper received at least two reviews. The programme chairs solicited additional expert reviews in cases where further clarity was warranted.

Only original, previously unpublished, research papers in English were considered and papers were reviewed according to South Africa's Department of Higher Education and Training (DHET) refereeing standards. Papers were reviewed according to the following criteria:

- Relevance of the paper to the conference theme
- Originality of the research contribution
- Technical/scientific merit of the research
- Presentation and clarity of the paper

Before accepting a paper, authors were to include the corrections as stated by the peer reviewers. The double-blind review process was highly selective. Of the 55 academic papers received for consideration, 27 papers were accepted for inclusion in the Proceedings after the required changes were made. This constitutes a 49% acceptance rate of contributed papers. The papers accepted cover a wide range of relevant topics within the conference theme, and are reproduced within these proceedings.

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The Program Chairs: SACLA 2015
July 2015

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Improving Program Quality: The Role of Process Measurement Data

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Abstract
In 2001 the "McCracken group", through a multi-institutional study, concluded that many students finishing their introductory programming courses could not program due to a lack of problem solving skills. In 2004 Lister established that students have a fragile grasp of skills to read and interpret code. Humphrey suggests that educators must shift their focus from the programs that the students create to the data of the processes the students use. This paper addresses the problem of poor performing students through an investigation of their quality appraisal techniques and development processes. Firstly, a case study was conducted to determine the current software development practices used by a group of undergraduate Computer Science students. Numeric data collected by means of a survey revealed that the current practices used by the majority of students would not be sufficient to produce quality programs. Secondly, an experiment was conducted to determine students' perceptions on the use of process measurement data to improve their current software development practices. Analysis of numeric and narrative data revealed that performance measurement data could provide students with useful information to adopt proper development practices.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer Science education.*

General Terms
Measurement, Performance, Design.

Keywords
Problem Solving, Code Reviews, Design, Personal Software Process, Undergraduate Education.

1. INTRODUCTION
Despite all the efforts of Computer Science educators to train students to develop software programs of the highest standard the programming performance of undergraduate students is often worse than expected. This can be attributed to the lack of problem solving skills [8] as well as poor code reading and interpretation skills [7]. Humphrey [3] created the Personal Software Process (PSP) that guides developers in the use of process measurement and quality appraisal techniques to improve the quality of their programs. He [3] suggests that educators must shift their focus from the programs that the students create to the data of the processes the students use. Various researchers conducted studies on the incorporation of PSP quality appraisal techniques into Computer Science courses [5] [6] [11].

The aim of this paper is twofold:

1. To discover which quality appraisal techniques and software development practices are used by undergraduate Computer Science students at a selected University of Technology.
2. To investigate the role of process measurement data as a contributor to the use of quality appraisal techniques.

2. LITERATURE REVIEW
In 2001 the "McCracken group" [8] conducted a multi-national, multi-institutional study in the United States of America (USA) and other countries during which they assessed the programming competency of Computer Science students who completed their first or second courses. They found that the majority of the students' programming performance was much worse than expected. Students indicated "the lack of time to complete the exercise" [8] as the major reason for poor performance. The research group also found that students struggle to abstract the problem from the exercise description [8] and therefore lack the ability to do problem solving. The group argues that students might have inappropriate (bad) programming habits because they treat program code as text and simply try to fix syntax instead of focussing on the task to be accomplished by the code. They suggest that future research should analyse narrative data gathered from students to gain better insight into development processes and problem solving behaviour.

Lister *et al.* [7] conducted a follow-up study on the McCracken group's research to investigate alternative reasons for poor programming performance. Their findings indicate that many students have "a fragile grasp of both basic programming principles and the ability to systematically carry out routine programming tasks, such as tracing (or 'desk checking') through code" [7]. According to Perkins *et al.* [9], students' code reading and interpretation skills can be linked to their ability to review and debug code.

Software quality can be defined as software that conforms to the user requirements [1]. Software review methods are widely used

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in the industry to improve the quality of software programs [2] [12]. Testing alone is seen as a very ineffective and time-consuming debugging strategy [12]. According to Humphrey [4], effective defect management is essential to managing cost and schedule during software development and also contributes to software quality. Humphrey states that testing alone is not the most effective way to remove defects. He proposes the inclusion of additional quality appraisal techniques such as inspections, walkthroughs and personal reviews. An inspection is a kind of structured team peer review process that was introduced by Mike Fagan [2]. Walkthroughs are less formal with fewer steps than inspections [12]. Fagan [2] concludes that a developer's productivity increases when he uses inspections because less time is spent on unit testing. Schach [12] indicates the advantages in time, cost and essentially project success when defects are picked up early in the development life cycle.

Humphrey [4] regards inspections and walkthroughs as team quality techniques. He proposes that individual developers should review their work before peer inspection, hence the term "personal reviews". He indicates that despite all the literature that guides developers on "good" practices and effective methods, the only generally accepted short-term priority for a software engineer is "coding and testing".

Humphrey [3] claims that one of the biggest challenges in software development is to persuade software engineers to use effective methods. Engineers tend to stick to a personal process that they develop from the first small program they have written and it is difficult to convince them to adopt better practices. Humphrey [4] created a PSP course in which a software engineer gradually learns to adopt his/her software practices according to personal measurements. The aim of the course is to improve program quality through personal reviews and to enable an engineer to make more accurate estimations based on personal historical performance data (collected by the individual). Analysis of thousands of PSP students' measurement data indicate that personal reviews improve program quality and that students spent less time in the testing phase if they use quality appraisal techniques. The course data also indicate an improvement on predictions based on historical data. Humphrey [3] states that PSP trained students in an educational environment will only use these methods if the educator grade them on the use thereof, and that most students will fall back on a process of coding and testing. He suggests that Computer Science educators must shift their focus from the programs that the students create to the data of the processes the students use. A number of studies have experimented with the incorporation of personal software process techniques in educational environments.

Jenkins and Ademoye [5] conducted a pilot and follow-up experiment in which students used personal code reviews to improve the quality of their individual programs. Since the pilot study indicated that students found it difficult to use the provided checklist, the follow-up study used a different approach by first training the students in tutorials how to use the checklists. As a result these students found it easier to use the checklist reviews. According to the students, the major problem they experienced with the provided checklist for code reviews was the time spent to do reviews. In both experiments the narrative feedback from the students indicate that they believe the process of using code reviews improved the quality of their programs although there are no concrete evidence to support this statement.

Rong, Li, Xie and Zheng [11] designed an experiment in which first year students used checklists to conduct personal reviews in order to ascertain whether checklist based reviews can effectively be used by inexperienced students. The authors concluded that checklists are helpful to guide beginner programmers during code reviews with the resulting review rates close to the suggested 200 lines of code (LOC)/hour benchmark prescribed by Humphrey [4]. They, however, found no concrete evidence that code reviews with checklists will improve the efficiency of the reviews. The study also showed that on average only 33% of the defects found during code reviews were found with the aid of the checklist – an indication that the checklist used were ineffective. For future research, the authors suggest finding methods to improve the effectiveness of checklists and investigating other factors that might influence the efficiency of code reviews.

Kemerer and Paulk [6] investigated the effect of review rate on defect removal effectiveness and the quality of software products. They analysed data collected by PSP course students and found that review rate is a significant factor for defect removal effectiveness. They also found the recommended review rate of 200 LOC/hour or less to be effective for individual reviews.

3. METHODOLOGY

This research study followed a mixed method approach based on the Framework of Integrated Methodologies (FraIM) as suggested by Plowright [10]. The context of this study was the Information Technology department at a selected South African University of Technology. The study was divided into two cases in order to distinguish between the two main sources of data [10].

In Case 1 a case study was conducted to gather information regarding undergraduate Computer Science students' perceptions of the quality appraisal techniques and software development processes they normally use when developing programs. The research population for this case included all first, second and third year Computer Science students at the selected institution. Data was collected by means of "asking questions" in a paper-based self-completion survey containing closed questions [10]. The survey was distributed and completed during normal lectures. A total of 251 students (the sample) completed the survey. This sample included 74 first year, 113 second year and 64 third year students. The numerical data collected through the survey was analysed in MS Excel and the results grouped according to the year-level of the respondents.

In Case 2 an experiment was conducted to gain a deeper understanding of students' development processes through the collection of actual process data. The population for this case included all third year Computer Science students at the selected institution. These students were selected since they already had intermediate programming skills and experience in software defect removal strategies. From this population six students were randomly selected to participate in the practical experiment. Data collection included observations, asking questions (post-activity survey and interviews) as well as artefact analysis (Process Dashboard© data) [10].

The Case 2 experiment consisted of four steps as summarised in Table 1. The instructor first conducted a tutorial activity to teach students how to log and interpret performance measurement data using the Process Dashboard© software. During this tutorial students were required to do an exercise in which they had to log time, size and defect measurements in different phases of the software development life cycle. The various defect types and examples of defects categorised into types were also discussed. After the tutorial the students completed an individual

programming exercise during which they had to capture performance data using the Process Dashboard© software. For this programming exercise the students had to implement the code to simulate the "Quick Pick Option" of the South African National Lottery (LOTTO©) draw[1].

Table 1: Experiment Design

	Activity	Duration	Rationale
1	Instructor presents performance measurement tutorial.	1 hour	Teach students to do process measures and interpret process data.
2	Students do programming exercise. Instructor makes observations.	3 hours	Capture process measures while doing programming exercise (Student). Record student behaviour and questions asked (Instructor).
3	Students complete post-activity survey.	15 – 20 min	Explore the students' perceptions of process measuring.
4	Instructor conducts interviews with students.	10 min (per student)	Gain deeper insights into students' development processes.

The students received an extensive background document on how "LOTTO" draws work. In the "Quick Pick Option" a user of the system first had to select the number of player lotto rows that should be generated. The requested number of rows then had to be generated randomly, sorted and written to a text file. Students could use any resources, including the Internet, to complete this activity. While the students worked on the individual programming exercise the instructor moved around the students and recorded his observations as well as all questions from the students. After this exercise the students had to complete a post-activity survey that consisted of mostly open-ended questions. The purpose of this survey was to explore the students' perceptions on the capturing and interpreting of process measurement data. In the final activity of Case 2 the instructor conducted interviews with all six students. During these interviews open-ended questions were used to gather narrative data regarding the students' development processes.

4. DISCUSSION OF RESULTS

4.1 Case 1: Pre-survey

Students first had to indicate how much of their development time is spent in each of the provided phases (see Figure 1). On average, students spent 25% of their development time on planning and design. They also indicated that most of their development time is spent on coding and contributes to 50% of the total development time. They spent 25% of their time on testing and debugging, which is roughly half the time that they spent on coding. Students of all year levels indicated almost similar results, which is an indication that a first year student and a third year student make use of similar development practices. It should be noted that the reported times are mostly estimates (individual perceptions) since only 16% of the students indicated that they record the actual time that they spent in the different development phases. The majority (88%) of students indicated that they do not use any time estimation techniques.

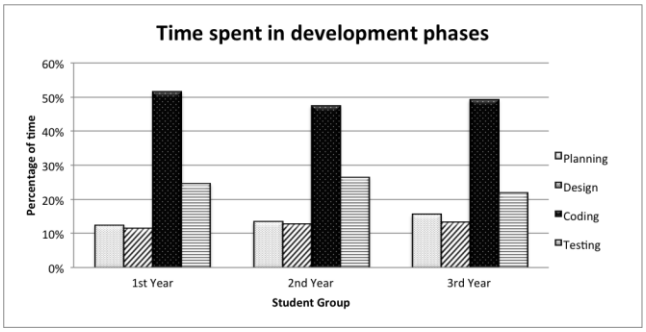

Figure 1: Estimated time spent in development phases

The next section of the survey focused on defect removal strategies. Students reported that they primarily use debugging for fixing defects as opposed to design and code reviews (see Figure 2). The use of design and code reviews increment slightly (10%) from first to third year students. Only 30% of the students indicated that they keep record of the defects they make.

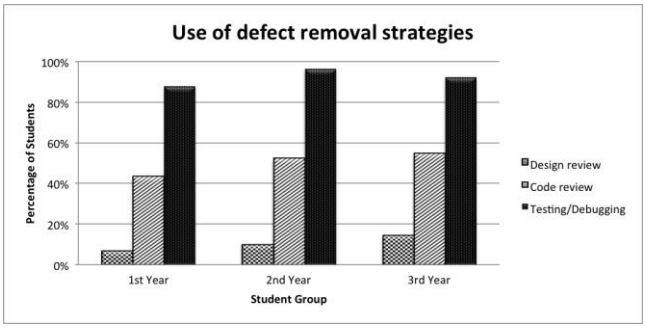

Figure 2: Use of defect removal strategies

Students were also asked to give an indication of the average mark they obtain for their programming assignments. As indicated in Figure 3 the reported average marks form a normal distribution curve around 59.5%.

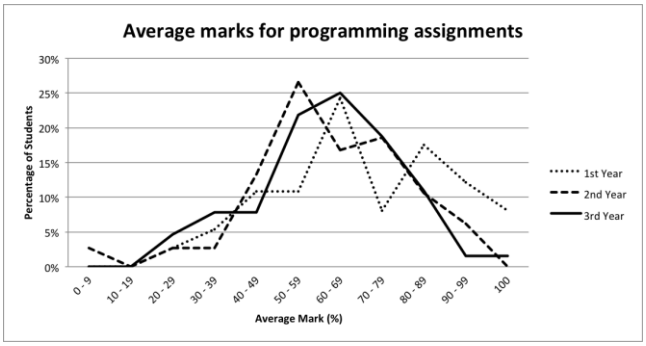

Figure 3: Average marks for programming assignments

Students then had to select (from three provided options) the main reason why they do not score full marks in all their programming assignments. The data analysis revealed distinct differences between the responses from the students in the different year levels (see Figure 4). The majority of first year students (54%) believe that their lack of programming skills is the major cause of poor results. Second year (47%) and third year (62%) students mostly put the blame on their inability to identify defects.

[1] https://www.nationallottery.co.za

Towards the third year fewer students (16%) regard their "lack of skill" as the major reason for failure. Although the students in all year levels regard "time" as a stumbling block to their success it is not seen as the major contributor (with values ranging between 17% and 27%).

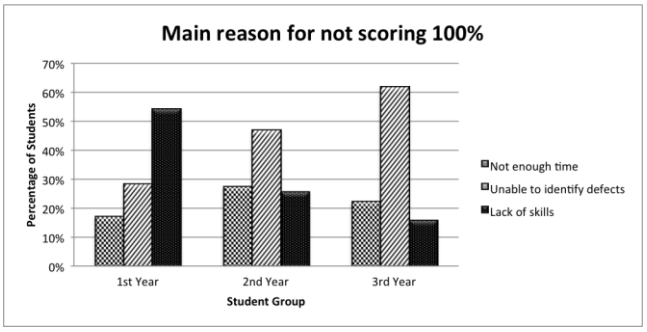

Figure 4: Main reason for not scoring 100% for assignments

When students were asked to indicate their preferred software development life cycle model the majority of second year (68%) and third year (63%) students selected "Code-and-Fix" (see Figure 5). It is not surprising that all the first year students selected the "Don't know" option since the first Software Engineering course is part of the second year curriculum. The senior students' reliance on code-and-fix strategies serves as an indication that they lack a thorough design phase in their development process.

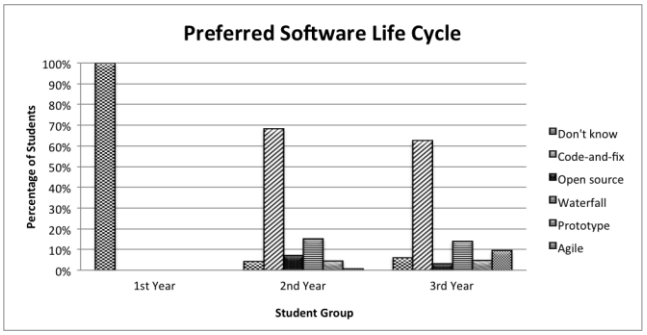

Figure 5: Preferred Software Life Cycle

Without a process that accommodates designs, students would spend little time on design reviews and therefore would not be able to identify defects early in the development life cycle. The students therefore have to rely on code reviews and debugging as their primary technique for finding and fixing defects. When using code-and-fix strategies the "thinking" process of "how to solve a problem" would occur during the coding phase – not during the design phase – which explains why students spent most of their time in the coding phase. Since the students indicated "debugging" as their primary technique for fixing defects (see Figure 2) it is no surprise that they struggle to identify defects. They treat the consequence of a defect, which makes it a lot more difficult and takes more time to find the actual defect. This also explains why students see the "identification of defects" as a major contributor to poor results (see Figure 4). This effect will increase towards the third year when assignments are larger – therefore making it more difficult to identify defects. The student, however, will not realise this because he/she is using exactly the same process that worked for him/her from the first year. This explains why there is almost no difference in the time spent in phases from first to third year (see Figure 1).

4.2 Case 2: Programming experiment

The discussion in this section considers the data that was collected during Steps 2, 3 and 4 of the programming experiment.

4.2.1 Instructor Observations

The instructor made the following main observations while the students were completing the exercise:

- Students searched the Internet to find solutions for the exercise.
- No designs were created to solve the exercise problem.
- Some students forgot to start and stop the Process Dashboard© timer when switching phases.
- Some defects were not logged.
- Students struggled to distinguish between the "coding" and the "testing" phase.
- Students struggled to describe their logged defects.

The students did not log the re-work coding in the correct phase. Most of them logged that time under coding, which explains why re-work or testing time was lower than coding time (also see Section 4.2.2). More precise measurements would result in much higher testing times.

4.2.2 Process Dashboard© performance data

The six students on average spent 135 minutes to create the program. This time frame included all phases of development: planning, design, coding and testing. Not one of the students in the group produced a fully functional program (according to the given specifications) during the allotted time frame. Two of the students had an almost working program (90% complete) while the rest of the students' programs could be graded 50% and less. The instructor decided to end the programming exercise after two and a half hours as enough useful experimental data was accumulated. At that time the students also indicated that they would not be able to identify and fix all defects even without a time limit.

On average the students spent their time as follows:

- 17% on planning;
- 1% on design;
- 0% on design reviews;
- 45% on coding;
- 1% on code reviews; and
- 36% on testing or debugging.

The actual time that these students captured while working shows a good correlation with the times reported in the pre-survey (see Figure 1). The actual testing or debugging time, however, would be much higher if these students had to continue to produce fully functional programs. On average 45 lines of code were produced by the students which resulted in a productivity of 20 lines of code per hour. Each student recorded an average of five defects with 90% of these defects injected during coding. The limited time spent on designs also serves as an indicator that most defects would be injected during coding. Ninety five per cent of the defects were removed in the testing phase – an indicator that debugging was used as the primary technique for defect removal. Given that only 1% of the time was spent in reviews would yield few defects (2%) to be found during reviews. No design reviews were conducted because of the lack of designs and only 1% of the

time spent on the design phase. This resulted in defects being discovered late in the development life cycle (testing), which makes it more difficult to identify them.

4.2.3 Post-activity survey

Students indicated that capturing time measurement data in the correct phases was easy but identifying and describing defects were difficult. For process improvement some students indicated that they would spend more time on creating effective designs and need to learn the skill to do effective reviews to pick up defects earlier in the life cycle. Most students were surprised by how much time they spent on testing and indicated that debugging might not be the most effective way to find and fix defects.

4.2.4 Interviews

An interview was conducted with each student in order to gain a deeper understanding of the development processes each one followed to create the program. The only artefacts that were created by the students (in addition to the captured Process Dashboard© measurement data) were the actual code. The students did not create designs and therefore these interviews focussed on what each student did during the problem solving process.

The students all indicated that their first step in solving the problem was to do an Internet search for possible solutions. They all found code that they thought could possibly solve the problem. They copied the code and then tried to change it to solve the problem. According to the students, this is the method they usually follow when completing their programming assignments.

In retrospect all the students indicated that they should rather have started by first solving the problem logically (using flowcharts or pseudo code) and then searching for code snippets to accomplish specific tasks. They also indicated that they do not find it easy to write pseudo code to solve problems and therefore prefer to search for code solutions where the logical thinking has already been done. Generally, they find it "hard to start" solving a problem.

5. CONCLUSION

In this paper various attributes contributing to the poor quality of student programmes have been mentioned. The findings of Case 1 revealed that most students rely on a process of code-and-fix, as predicted by Humphrey [3]. Code-and-fix remains the predominate process of choice from first to third year level which indicates no process improvement through the years of study. Students also regard "testing" as the most effective strategy to remove defects. After a selected group of third year students participated in a practical experiment (Case 2) they – through the use of process measurement data – realised that they have to improve their design skills in order to create better quality programs. These students also realised that quality products are produced through quality processes that include quality appraisal techniques. We can therefore conclude that undergraduate students need more extensive training to reach a level where reviews would become an effective defect management strategy. The various methods and tools that can be used to teach students how to perform effective reviews need further investigation. The students' personal reviews indicated that they also lack design and problem solving skills. This provides further verification for the findings of McCraken *et al.*'s study [8]. Future research could therefore also focus on methods that can be used to teach proper problem solving and design skills. It is also recommended that instructors enforce effective design techniques from the first programs that students write to ensure that they will not fall back on a "code-and-fix" life cycle. This study has shown that the effect of process measurement data should be regarded as a valuable contributor to any process improvement changes educators want to enforce on students. The ultimate ideal is that students would be able to adapt their processes according to their personal data.

6. ACKNOWLEDGMENTS

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Applying Human-Computer Interaction (HCI) Design Principles and Techniques in HCI Course Design

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ABSTRACT

In this paper we investigate the applicability of HCI design principles and techniques to course design – specifically HCI course design. User centered design (UCD), user experience (UX) and participatory design (PD) are some of the core concepts and techniques that we teach students in HCI, but do we as HCI experts apply these when we design our courses? In the case study discussed here we allowed a class of honours HCI students to help us design the very course that they were studying, through a PD exercise at the start of the course. The course time spent on this design activity was not wasted, since it served as an experiential learning exercise whereby students learned how to do UCD through PD. The motivation for using UCD in human-computer interface design is to create a usable interface and improve the UX. Student evaluation of the HCI course indicated a very positive learning experience and we propose that just as UCD and PD in HCI improves UX, applying these principles and techniques to course design improves the student experience.

Categories and Subject Descriptors

K.3.2 [Computer and Information Science Education]

General Terms

Design, Human Factors, Theory

Keywords

HCI course design, Participatory design, User centered design, Experiential learning

1. INTRODUCTION

The importance of human factors in information technology (IT) design and an increase in demand for human-computer interaction (HCI) specialists in South Africa has motivated the Department of Informatics at the University of Pretoria to introduce a postgraduate HCI course into their BCom Honours degree in Informatics (i.e. Information Systems). The HCI course, INF790, was offered in its current form for the first time in the second semester of 2014. The primary aim with the module is to teach Informatics students how to design interactive IT user interfaces that maximise effectiveness, efficiency and user happiness. Students learn how to use formal, user centered, user experience (UX) and usability design and evaluation methods and they should acquire the skills to understand and communicate with the intended users. In designing and delivering this course we applied these same principles and techniques that we intended to teach.

Fincher, Cairns and Blackwell [11] write: "As HCI researchers and practitioners, we are careful to pay close attention to user communities, their wants and needs. We engage in user studies, ethnographic investigation, participant observation, and contextual and participatory design exercises. However, as educators, we do not take such care. We tend to create (and re-create) courses and materials relying on how we were taught, or how other subjects around us are taught, without reference to the particular challenges of teaching HCI" (p. 2707). Lecturers teach HCI students about user centered design, user experience and how important it is to understand users and involve them in the design process, but do they (and should they) apply these principles when designing the HCI courses that they teach?

The literature on the application of HCI in educational design is primarily concerned with the design of technology-based learning systems and not with the design of lecture-based or blended teaching and learning. We could not find any reports on HCI course design where the students were co-designers of the syllabus or the delivery mechanisms. One argument against such an approach could be that there is limited teaching time and much to cover, so it would be difficult co-design the course with students and offer it in the available time. We propose that the solution is to use the participatory course design exercise as a means to teach students some of the fundamental HCI principles, methods and practices. Participatory design is a design technique that allows those who will use or benefit from the designed artifact to contribute to the decisions made during the design process [2, 12].

Allowing students to co-design their course would create an experiential learning experience whereby students could acquire participatory design skills such as planning and executing a participatory design study, gathering and analysing information from various sources to inform their design (users, experts,

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research articles, the Internet), presenting design ideas and evaluating the design.

In the research reported here we investigated whether we could use the application of HCI design principles and techniques in designing the INF790 syllabus as a hands-on example while teaching the students about these same practices. In other words, the INF790 students had two roles: firstly they were the users who we were designing the course for and who were therefore consulted during the design, and secondly, they were the students of INF790 who were acquiring HCI knowledge and skills.

Our aim was to establish whether we could, by applying HCI principles in our teaching and learning design, create an HCI course that is accessible and engaging to students, that meets the students' needs, and provides them with an enjoyable learning experience overall.

The research question was: Can HCI design principles and techniques – particularly those focusing on user centered design and participatory design – that we teach students in an HCI course, be applied successfully to the design of that same HCI course to make the teaching and learning more accessible and engaging and give the students a positive learning experience?

We organise the discussion as follows: In section 2 we discuss related work focusing on participatory design, user centered design and user experience design. The methodology is described in section 3, including a description of the case, the implementation plan and the data collection and analysis methods. In section 4 we present the results and conclusions and end the paper in section 5 with plans for future work.

2. BRIEF REVIEW OF RELATED WORK

From an HCI theory perspective, our focus was on user centered design and participatory design. From an educational theory point of view, this research relates to constructivist and experiential learning. In this discussion of the related work we focus on these concepts, but also discuss some aspects of HCI curriculum design.

2.1 User centered design

User-centered design (UCD) is a process in which the needs, characteristics and limitations of end users are the main focus during each stage of the design process. It requires designers to analyse how users are likely to use a product and how to best support them in this. It requires that the validity of assumptions with regard to user behaviour is tested in real world scenarios with actual users. Involving users is essential because designers cannot know intuitively how a first-time user will experience a design and what the learning curve will be. UCD aims to optimise the design around how users will use the product, rather than expecting users to change their behaviour to accommodate the design.

UCD is based on [4]:

- Early focus on users and tasks: directly studying cognitive, behavioural, anthropomorphic and attitudinal characteristics.
- Empirical measurement: users' reactions and performance to scenarios, simulations and prototypes are observed, recorded and analysed.
- Iterative design: when problems are found in user testing, they are addressed and re-evaluated.

Similarly, in learner centered design (LCD) the needs of the learner and not the teacher are the central point of design [16]. Applying UCD principles in course design (as was our aim here) is a form of LCD.

A design method that supports user centered design is participatory design.

2.2 Participatory design

Participatory design (PD) is an approach that involves end-users of a technological or organisational system in the design and decision-making processes associated with that system [2]. It originated in Scandinavia in the 1970s with the aim of providing a mechanism whereby workers could voice their opinions with regard to design of new technologies for use in their workplace [8]. PD was driven by the democratic ideal that the people who are affected by the outcome of design decisions should have the opportunity to influence the design [3]. Gregory [12] gives the following additional reasons for including users in the design process:

- Improving the knowledge required to create the system.
- Reducing resistance the user may have when confronted with the new system, that is, to make sure they have realistic expectations.

PD can also be applied in educational design [7]. Universities are increasingly involving students in content creation and design. They do this by establishing spaces and opportunities for students to learn and create knowledge together [13].

PD is a cyclic process that includes critical examination of the effect of design decisions made in earlier cycles. According to Spinuzzi [17], PD includes the following three stages:

1. Initial exploration of whatever is being designed or redesigned. Designers become familiar with the users' world and how they operate.
2. Discovery, during which all participants (designers and users) understand and prioritise the current situation and envision future systems. Users' goals and values are clarified and they come to an agreement on the desired outcome.
3. Prototyping, that allows designers and users to create the outcome in an iterative process according to their vision formulated in the second stage.

PD is inherently a constructivist method in the sense that knowledge is created through the interaction between participants in the design process [17]. Designers or researchers who engage in PD act as facilitators in a process of empowering users to influence decisions. A PD exercise therefore translates naturally into a constructivist learning experience.

2.3 Constructivist and experiential learning

The constructivist approach to learning promotes the personal creation of knowledge. Learning is seen as an active process during which learners construct new ideas or concepts based upon their current and past knowledge [4]. The learner's individual interpretation of the learning content and context is the primary reality. According to De Villiers [6], constructivism "aims to instill personal goals and active involvement within real-world situated learning, leading to application skills and transfer" (p. 359). In this study, co-designing the course provided the real-world goal. The knowledge and skills that students gained while engaging in participatory course design, would then be transferred to PD in the general HCI context.

Experiential learning (EL) can be regarded as a form of constructivist learning. Prominent 20th century scholars such as John Dewey, Jean Piaget and Lev Vygotsky placed experience at the center of their theories of learning and provide the foundation for EL theory [14]. The focus in EL is on application of knowledge to real-world situations, with the teacher acting as facilitator [18]. EL can happen in a classroom through the use of case studies and simulations and other embedded activities. Kolb's widely used experiential learning cycle consists of the following components [18]:

1. Experience: Students engage in hands-on experiments or activities that provide them with experience of a real-life situation.
2. Reflect: Students reflect on their experience with peers and/or an educator to make sense of it and relate it to their prior understanding.
3. Conceptualise: Students develop a new understanding or modify an existing understanding.
4. Test: New knowledge is tested through application.

2.4 HCI curriculum design

According to Churchill, Bowser and Preece [5], the issues that led to the development of HCI as a discipline are still the ones that are focused on today, e.g. the usability and learnability of technologies and how users react to them. Aesthetic attraction and emotional appeal are also important since some forms of technology have gone beyond functional objects to become fashion objects. Against this background, Churchill, et al. [5] set out to identify the current core issues of HCI and how this impacts on the teaching of HCI. Their 2013 study confirmed the 1992 ACM Curricula for Human-Computer Interaction report (http://old.sigchi.org/cdg/index.html1992) that failed to identify a generally agreed upon range of topics that clearly delineates the HCI discipline.

The ACM and IEEE [1] include the ten topics listed in Table 1 in their proposal for HCI in the Computer Science curriculum. The first two are regarded as core topics while the rest are electives. Since our HCI course is part of an Informatics (or Information Systems) degree and not Computer Science, not all of these are appropriate for our students given that their prior knowledge comprises information technology management and information systems design, rather than programming and formal aspects of computer science. We indicate in the last column how we incorporated these recommended topics into our syllabus. We only provide the details on those we did include. (As we will explain in section 3.3 below, our syllabus included some additional topics not listed in this curriculum.)

2.5 Conclusion: how these concepts relate to our study

We end this selective review of the related work by summarising its relevance to the research reported in this paper.

During the design of the INF790 module we applied the principles of UCD regarding our students as the "users". By creating opportunities for students to reveal their needs and preferences we gathered information that guided us in making curriculum choices and selecting assessment mechanisms that would best support their learning. Although we started with some assumptions about what to include in the course, we tested these assumptions right at the start of the course with the real students of the course and adapted the content to their needs where these were well motivated.

PD provided the mechanism to get early input from our students, thereby involving them in the design and decision-making processes associated with the course they would be doing. By using PD in this way we aimed to achieve the outcomes usually associated with PD, namely promoting a democratic course design process; improving the knowledge required to develop the course; and to make sure the students have realistic expectations about the course (thereby reducing resistance and improving engagement).

The two core topics that should form part of the HCI curriculum as described in ACM and IEEE [1] are Foundations of HCI and Designing Interaction. They include subtopics such as "human-centered software development", "the user-centered design process", "needs analysis for an identified user group". The idea of giving students hands-on experience in UCD through a real life PD exercise is thus well aligned with these core curricular requirements.

Following a constructivist, experiential learning approach our students were confronted with a real life design task (the design of INF790). While participating in this design task during the actual INF790 lecture time they learnt in practice what user centered design is and how to conduct a participatory design exercise.

Next we give a detailed account of our approach in conducting this study.

Table 1. HCI topics recommended by the ACM and IEEE

Topic	Included in our syllabus
1. Foundations of HCI (CORE): human-centered software development; basic precepts of psychological and social interaction; conceptual vocabulary including affordance, conceptual model, feedback, etc.; the user-centered design process; usability testing.	All
2. Designing Interaction (CORE): needs analysis for an identified user group; creating a simple application with help and documentation that supports a GUI; conduct a quantitative evaluation and discuss/report the results; user interface design standards.	All except the creation of an application.
3. Programming Interactive Systems	None
4. User-Centered Design and Testing: how user-centered design complements other software process models; low fidelity prototyping to gather/report user responses; choosing appropriate development tools for a specific UI; comparing / selecting appropriate evaluation techniques for a given UI.	All
5. New Interactive Technologies: non-mouse interfaces (use, appropriateness, advantages and disadvantages).	Superficial overview
6. Collaboration and Communication: synchronous vs. asynchronous; individual vs. group; social concerns; human intention.	Superficial overview
7. Statistical Methods for HCI	None
8. Human Factors & Security	None
10. Design-Oriented HCI: HCI as a design-oriented discipline; the processes of design appropriate to specific design orientations; apply a variety of design methods to a given problem.	Overview, but PD in practice
Mixed, Augmented and Virtual Reality	None

3. RESEARCH METHODS

The research question that guided our research was: Can HCI design principles and techniques that focus on UCD and PD be applied successfully to the design of an HCI course to make the course more accessible and engaging and give the students a positive learning experience? We used a case study in answering this question. Our discussion of the methods is therefore structured around aspects associated with case study research.

3.1 A case study: participatory design of the INF790 module

A case study is an in-depth inquiry into a specific real-life instance of the object or topic under investigation [15]. Other characteristics of case study research are: examination in context; the use of multiple data sources; and emphasis on qualitative analysis [15]. All of these apply to our research. Data collection and analysis within a case study is usually guided by some theoretical framework.

In our research we investigated the application of HCI principles and techniques in the design of an HCI course by using such principles and techniques to design a specific HCI module. Data were collected by following the HCI principles of user centered design (see section 2.1) and the processes associated with participatory design (see section 2.2). Data sources included the design outcomes of a PD session, responses to surveys, student assignments and marks (discussed in detail in section 3.4 below). Although some of the data were quantitative, analysis was primarily done qualitatively (see section 3.5).

The research was conducted in a real life context during the second semester of 2014 when the case course – INF790 – was presented for the first time in its current form in the Informatics department at the University of Pretoria (UP). It started on 25 July and ended with a written examination on 18 November 2014. Since many of our honours students study part time, there are eight two-hour lectures per module that take place broadly every second Friday.

Ethical clearance to conduct this research was granted by the Faculty of Engineering, Built Environment and Technology.

There is a general expectation in our department that the course content will follow the ACM and IEEE curriculum guidelines, but decisions about the course structure, content and delivery mechanisms lie with the course coordinator who takes responsibility for the course. The lecturer also decides on the formative and summative assessment in consultation with an expert external examiner. In this course, the mark obtained for formative assessment (assignments) and summative assessment (examination) each counted 50% towards the final module mark.

The course carries 15 credits and a total of 120 credits are required for the degree.

3.2 The participants

The first author was the lecturer responsible for the design and presentation of the course. The second author acted as objective observer throughout the course and conducted the final evaluation session with the students.

The students who participated in the study were all registered for the BCom Honours (Informatics) degree in the Informatics department at the University of Pretoria and chose INF790 as one of their elective modules.

When the course commenced, 27 students were registered for INF790. Thirty-nine (39) students attended the first lecture since

it is common practice for students to only decide after the first lecture which modules they will continue with. Eventually 41 students actively participated in the module.

The prerequisite to study the honours Informatics degree at UP is an undergraduate degree passed with a minimum average score of 60% for Informatics on third year level or 60% for equivalent IT courses. In the class of 41 only two students had previously studied HCI as part of an undergraduate course.

3.3 The participatory design process

We needed to conduct the participatory course design exercise in the first lecture so that the design outcomes could be implemented in the remainder of the semester. Following the PD cycle as described in section 2.2 the first iteration was planned as follows:

3.3.1 Initial exploration

The lecturer did an extensive survey of what is taught in HCI courses across the world. This was done by consulting web pages of leading universities (e.g. MIT and Stanford) to find out what they include in their HCI curricula. We also obtained information by reviewing scholarly articles on HCI teaching (e.g. [5], [9], [10], [11]), as well as the ACM and IEEE recommended curriculum [1]. The lecturer/designer also gathered information on the career expectations of Honours BCom Informatics students in order to understand the kind of positions the INF790 students will typically apply for after graduation.

3.3.2 Discovery

What was learnt during the initial exploration was shared with the students so that all participants (designer and students) understood the current scope of the HCI field and the topics commonly taught over the world. The lecturer identified ten core HCI topics that could potentially be covered during the course, namely Interaction design; Social impact of technology; HCI and education; Eye tracking; Designing for special user groups; Usability and UX evaluation; Cognitive psychology; Designing online communities; Data visualisation; and HCI for IT managers and BAs.

Eye tracking was included because this is the lecturer's field of expertise and we were in a position to teach the students to use the equipment in practice. Since eye tracking provides a dependable, objective way to evaluate usability, including eye tracking aligns with the recommended curriculum. Data visualisation was added since data-centered design has become a widely taught HCI topic and, as potential business analysts (BAs), the inclusion of data visualization provides the students with relevant skills. Finally, HCI for IT managers and BAs was included to align with content covered in the undergraduate BCom degree, and also to explain to the students how all these skills could fit into their careers.

During the first lecture, a five minute overview of each topic was presented to convey to students its essence. Students were also presented with three possible summative assessment formats that the lecturer would consider based on more than ten years' experience as examiner of HCI courses:

1. Traditional closed book examination based on the text book and course notes and consisting mostly of theoretical questions.
2. Six essay questions (one on each lecture respectively) of which you have to do four in the exam. Questions are NOT available beforehand, but the exam is open book.
3. Six essay questions to prepare before the exam. Any three of these will be in the exam plus one unprepared essay.

Students' goals, values and preferences were clarified through surveys and small group presentations.

3.3.3 Prototyping (and further discovery)

After the overview, students were divided into six groups consisting of four to ten students. They were randomly allocated to groups for as follows: on entering the class, each student selected a small chocolate from a jar. The chocolate brand determined the group allocation (e.g. all *Aeros* formed one group).

The student groups were requested to design, in their groups, a course syllabus that included any selection or combination of topics from the ten topics introduced. They were also asked to consider the assessment choices and decide on their choice of summative assessment format. After 20 minutes design of time, each group gave a 5 minute presentation of their suggested syllabus.

Although participants did not construct physical prototypes, they created posters that outlined their designs of the syllabus (see section 3.4). The posters formed part of the data for this part of the PD exercise. To motivate students to do this thoroughly they were given marks for this activity that counted towards their semester mark.

During the presentations all participants could discuss and comment on the suggestions. This contributed to the "discovery" phase in that students could learn what their fellow students' needs and preferences were.

After the presentations students completed an individual survey on Google Forms to rate the 10 topics from most preferred to least preferred. The lecturer made the complete set of survey data available to all students. A pair assignment was then given that they had to complete within a week. This involved creating a visualisation of the data gathered during the rating exercise. This assignment also contributed to the discovery phase of PD as students would then, by analysing all the survey responses and creating the visualisations, form a clear idea of the whole class' preferences. These visualisations formed part of the data set for this study.

The results of the survey as well as the group presentations were analysed to formulate the final syllabus to be covered in the remaining lectures (see sections 3.5.1 and 3.5.2).

In the second lecture, the results of the PD exercise and the survey results were presented to students and the class reflected on the

PD activity and the validity of its outcomes. Students openly expressed their appreciation of allowing and using their input into the course design.

3.3.4 Evaluation

During the sixth lecture, students completed the university's standard course/lecturer evaluation questionnaires and in the final lecture we asked the students to complete an open ended questionnaire to get more detailed feedback.

At the end of the course, students were given a second chance to rate the ten topics. The results of this rating was compared to the initial rating to determine if students had changed their preferences after becoming better informed about HCI in general (see section 3.5.1). One of their examination questions required them to create a visualisation to compare the outcomes of the two surveys.

3.4 Data collection

Case study research is characterised by the use of more than one data collection technique. Following the procedure described in section 3.3, we gathered the following data using a range of methods and instruments:

3.4.1 The results of the topic preference surveys

The topic preference surveys were conducted at the beginning and end of the course respectively. As an assignment on Data visualization, students produced visualisations that reflect the results of the two surveys. Two examples of these visualisations are shown in Figures 1 and 2. Figure 1 shows a 'wordle with the prominent choices in larger fonts. Figure 2 presents the results in a bar chart, showing the favourites in differently coloured bars.

Figure 1. A wordle produced by a student to represent students' topic preference

3.4.2 Small group presentations

The posters created by the groups who presented their proposals for a course syllabus during the PD session in the first lecture were also included in the data set. Figure 3 shows a poster of a group who included the social impact of technology, eye tracking and the design of online communities in their syllabus. They also clearly indicated which examination format they preferred.

3.4.3 Class participation

Student participation was reflected in e.g. class attendance, participation in group activities and assignment submission

3.4.4 Student results

This included results for five assignments, one class test and one written examinations.

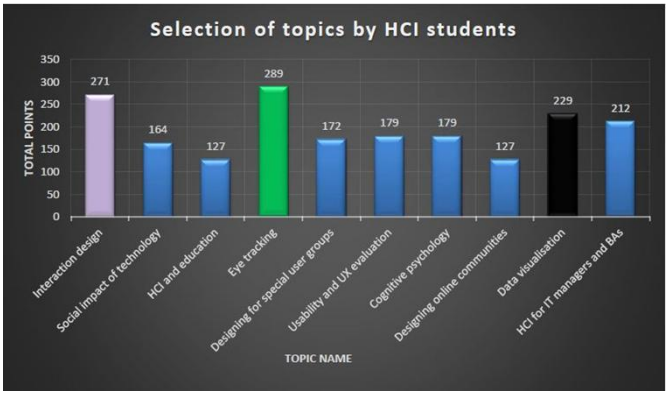

Figure 2. A graph produced by a student to show students' topic preferences in beginning of the course

.

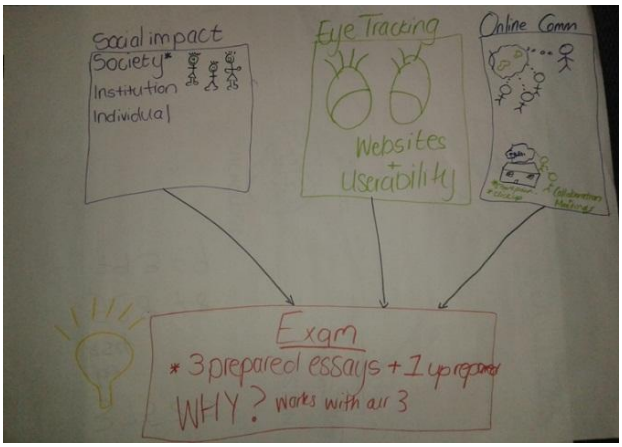

Figure 3 Curriculum design demonstration poster

3.4.5 Student evaluations of the course/lecturer

Feedback through the university's course evaluation procedure covered the aspects and criteria listed in Table 2. In this standard evaluation form, each aspect is evaluated using a five point scale (1 = negative to 5=positive) and space is provided where students can write open ended comments. We considered the possibility that the results of the standard evaluation may be biased in the sense that only students who had something positive to say would provide comments. For that reason we did a further evaluation that were designed to prompt negative comments. Only two questions were asked, namely:

1. List at least three things you would change about the course.
2. It seems from the evaluation that the level of difficulty of this module might be below what is expected at honours level. Please comment on this.

Table 2. Standard course evaluation criteria

Area	Criteria
Module Content	Organization Study material Usefulness of material for completing course Usefulness of course
Lecturer(s)	Interpersonal relationships with students Level of knowledge Attitude Preparation, use of media Learning opportunities
Assessment	Clarity of criteria Nature, content and method Fairness

3.5 Data analysis

Our aim with the research was to determine whether HCI design principles and techniques such as user centered design and participatory design can be applied successfully to design an HCI course, thereby making the course more accessible and engaging and give the students a positive learning experience. Data analysis was guided by this aim and therefore focused on evaluating the success of the PD activity in terms of:

- The usefulness and practical applicability of the design outcomes for actual course design
- Whether students actually acquired knowledge and skills of UCD and PD by participating the this experiential learning exercise
- Its contribution to students' engagement, enjoyment and achievement during the course.

We summarise the results of analysis of each of the data sources in turn and then synthesize the outcomes in section 4.

3.5.1 Topic preference surveys

The same survey was completed by students twice – one in the beginning of the module and one at the end. They had to rate the ten topics by assigning 1 to the one they liked most and 10 to the one they liked least. No two topics could receive the same score.

The first survey was completed by 36 students and the second by 41 students. Figure 4 shows the results, comparing the average ratings for each topic. The green (bottom) bar represents the October ratings and the blue (top) bar the July ratings. Eye tracking remained the clear favourite receiving an even higher score (8.4) at the end than at the beginning (8.3). The most significant change of opinion relates to Usability and UX evaluation, which received an average score of 5.1 in the beginning of the course and 7.4 by the end of the course. The scores for Cognitive Psychology and Designing Online Communities also increased. Interaction design which received the second highest score in the July survey (7.7) dropped notably and at the end of the course (with 6.7) was third in line after Eye tracking (8.4) and Usability and UX evaluation (7.4). Data Visualisation dropped from third to fourth position.

The three topics with the lowest scores in July were HCI and Education, Designing Online Communities and Social Impact of Technology. In October, HCI and Education was still the least popular, then Designing for Special User Groups and again the Social Impact of Technology. (Note that none of these were included in the syllabus, so students did not necessarily have more knowledge on these when doing the second survey.)

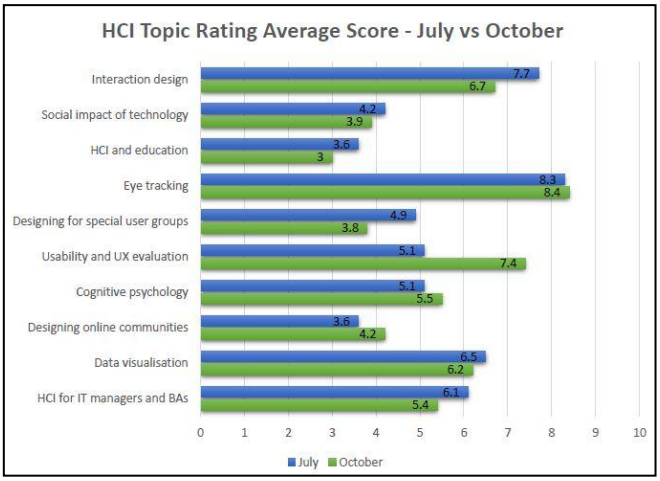

Figure 4. Results of the topic rating survey

3.5.2 Analysis of posters/presentations

Analysis of the posters and presentations made by the six groups in the PD activity revealed the following:

- All six groups included Eye Tracking in the syllabus.
- Five of the six groups included Interaction Design.
- Four groups included Data Visualisation.
- Usability and UX Evaluation, Designing for Special User Groups and Cognitive Psychology were all included by two of the six groups.
- Social Issues in IT Use, Designing Online Communities and HCI for Business Analysts were each proposed by only one of the six groups.
- The only topic that no group included was HCI in Education.

Figure 5 gives a graphical overview of these results relating to the topics (e.g. Group 1 included Interaction design, Eye tracking and Data visualisation; Interaction design was selected by all groups except Group 2).

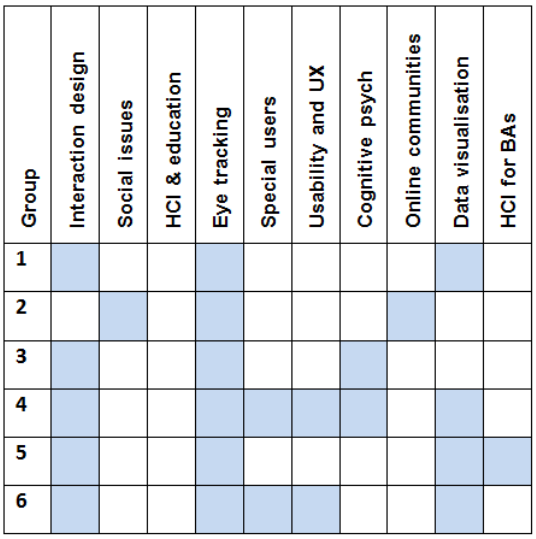

Figure 5. Topics included in syllabi designed by groups

Comparing the results of the group presentations with the individual rating of topics revealed the following differences between individual choices and group preferences:

- Although the same number of individuals preferred HCI for BAs and Data Visualisation, the latter was selected by four groups while HCI for BAs was selected by only two groups.
- Group 3 selected Cognitive Psychology, although both Data Visualisation and HCI for BAs scored better amongst individuals in the group.
- Group 5 selected Data Visualisation although the individuals in that group clearly preferred HCI for BAs.

These discrepancies could have been caused by stronger personalities in the group determining the group choices. This was confirmed by comments in the course evaluation data that asked for individual input only.

Based on the results of the first topic rating survey and the analysis of the syllabi presented by the students, the syllabus given in Table 3 was decided on for INF790. Five of the six groups chose the third examination format (three prepared essays and one unprepared one) and one group wanted the traditional closed book examination.

3.5.3 Analysis of student class participation

During four of the eight lectures there were class activities or a test for which students received marks that counted towards their semester mark. Besides the one class test which they prepared for, the students did not know in advance whether a class will involve activities for which they will receive marks. There was no attendance lists but from the marks allocated for these activities we deduce that lectures were attended by anything from 36 to 40 of the 41 registered students. This is a very high attendance rate given that these are part time students. Table 4 describes the attendance of the four lectures with class activities/tests.

Table 3. Co-designed syllabus for INF790

Week starting	Topic
1 Aug	Interaction Design: requirements; defining the problem space; user characteristics; cognitive psych
15 Aug	Interaction Design: design; guidelines; prototyping; participatory design; interface metaphors/layout
29 Aug	UX & Usability Evaluation: Overview of evaluation methods
5 Sep	Eye tracking: Theory and practical demo.
19 Sep	Eye tracking: Group demos of homework assignment; feedback and reflection.
3 Oct	Data Visualisation
7 Oct	Summary (HCI for BAs)

Table 4. Class attendance deduced from class activity results

Lecture	Activity	Number submitted
1	Group presentation for PD activity	37
2	Requirements analysis group activity	40
4	Class test	36
7	Data visualisation group activity	36

3.5.4 Formative and summative assessment results

Summative assessment comprised five assignments – a pair assignment, one where students had a choice between individual and pair, one individual and two group assignments. The high average score for the group assignments can be attributed to the fact that the quality was determined by the top achievers in the groups. Of the 39 students who wrote the examination, only two failed. Table 5 summarises the assessment data.

Table 5. Assignment and Examination data

	Type	No submitted	Ave. score
Ass 1	Pair	40	64.4%
Ass 2	Pair or individual	41	78.8%
Ass 3	Individual	41	63%
Ass 4	Group	41	76.4%
Ass 5	Group	36	80.4%
Exam	Individual	39	66.2%

3.5.5 Course/lecturer evaluation

First evaluation (after the 6th lecture):

The first evaluation was the standard course/lecturer evaluation that is done for all modules in the department. A departmental administrative officer facilitates this while the lecturer is not

present. The anonymous feedback is recorded and analysed and then sent to the lecturer in electronic format.

This evaluation of INF790 was very positive overall. Of the 41 registered students, 33 completed the questionnaire. The average score out of 5 for each criterion is given in Table 6. The overall score for the course was 4.48.

The open ended comments in the first evaluation were also very positive. Since we were particularly interested in the usefulness and practical applicability of the PD exercise, the value of the experiential learning exercise and the general student experience, our analysis of the comments focused on finding information related to these.

Nineteen (19) of the 33 respondents commented on "Module Content (Organisation)". Eight of these made specific mention of the participation in the course design, for example:

"It was a great idea to get students involved in selecting areas of the subject they would like to focus on. Good, clear road map"

"I enjoyed the fact that we could choose the schedule and topics"

"It was great to choose our own topics. In future maybe not make this a group exercise as not everyone feels the same maybe shy to say"

"I appreciate that we were actively part of deciding on the syllabus"

"Syllabus clear as we got too select it content clearly states to do what"

Seventeen (17) students commented on "Module content (Usefulness of course for career)". Only one doubted the usefulness for his/her career saying: "*I think it is very insightful but as a B.IT student I think there are other things that will be more important."* All the other comments were positive – for example:

"I can see how it would play a role in certain career choices"

"This course has elements/topics which any organisation can benefit from"

"I have been asked by Standard Bank if I have HCI experience - This helps."

"For me (BA) it is useful because I design all our screens."

One danger in asking students to contribute to the design of the syllabus is that students may think the lecturer is trying to transfer some of his/her duties to the students. Comments on Lecturer (Level of knowledge) criterion countered this. Ten of sixteen responses included words such as *"very knowledgeable", "clearly knowledgeable"* or *"very experienced"*. Students also clearly appreciated the inclusion of real life experiences in the lectures, saying for example:

"Shares experiences which is good for learning."

"Lecturer is experienced and always shares her experience & knowledge"

Table 6. Results of standard course evaluation

Area	Criteria	Score
Module Content	Organization	4.52
	Study material	4.18
	Usefulness of material for completing course	4.24
	Usefulness of course	4.33
Lecturer(s)	Interpersonal relationships	4.61
	Level of knowledge	4.79
	Attitude	4.85
	Preparation, use of media	4.82
	Learning opportunities	4.42
Assessment	Clarity of criteria	4.30
	Nature, content and method	4.21
	Fairness	4.48

Four of eleven comments related to "Lecturer (Learning opportunities)" indicate that students value real life experience:

"Opportunities to use equipment that is used in the industry was fantastic"

"There are a lot of learning opportunities to apply ourselves"

"Work activities helped improve understanding"

"Good useful experience with tasks".

With regard to general learner experience, we analysed student feedback on "Comment (Level of difficulty)", "Comment (Work load)" and "General comments". The first of these received 32 comments and in seven of them students used words such as "fun", "interesting", "enjoyable" in the sense that the level of enjoyment made up for the level of difficulty.

Thirty-three (33) students commented on the work load. Eight said the work load was too heavy and one thought it was easy. The other 22 all used words such as "manageable", "average", "acceptable", "fair" and "achievable" to indicate that they were satisfied with the work load.

Twenty-eight students made general comments and here we learnt the most about the user/student experience. Twenty-three expressed clear enjoyment, for example:

"So glad this was introduced in the syllabus. An interesting subject in which we as INF students have not yet had experience in."

"I have really enjoyed the module thus far. It has made me think differently on many aspects of system design and life in general."

"So far I've been intrigued by the course. I thought it would be fun, but not so much fun. I truly enjoyed taking this course."

"By far the best, useful and interesting subject of my whole year"

"I wasn't sure what to expect but I learned a lot and this course has spiked my interest into considering this as a future field and learning more on it."

The negative comments were:

"Would have enjoyed the course more if we had more chances to innovate"

"Too much group work, presents challenges to new students"

"There may have been a lack of generalised view of HCI. Large focus on specific aspects like eye tracking"

"Lectures are a bit long, too much theory"

"May be add more practical work instead of all the theory".

Second evaluation (after the final lecture):

We considered the fact that the predominantly positive feedback may have been caused by demand characteristics response bias (i.e. the students adjusted their responses to fit the expectations of the lecturer). With the second student evaluation we specifically asked students to list things that they would change about the course. Twenty-two students answered this question. The most prominent requests were:

- Fewer assignments – five students mentioned this. Two more asked for fewer group assignments and more individual ones. There was, however, one respondent who specifically asked for more assignments.
- More practical work – nine students requested this, but in different ways. Some wanted practical work in class to replace the theoretical parts of the lectures. Two asked for more practical eye tracking work (although two other students specifically asked that eye tracking be omitted from the course). Two students asked for practical work that would involve programming.
- A broader range of topics – three students asked for more HCI topics to be covered, but, on the other hand, one student complained about too much breadth and too little depth.

In this evaluation, there was only one respondent who referred to the PD activity. He/she did not appreciate the fact that students co-designed the syllabus, saying the *"structure of the course should be planned out in advance by the lecturer".*

The second question asked about the level of difficulty. The responses confirmed what was found in the first evaluation: a few thought it was easy, some thought it was difficult or demanding in terms of time and effort, but the majority felt it was fair and comparable to other honours modules.

4. RESULTS AND CONCLUSIONS

We investigated the applicability of HCI design principles and techniques to the design of a specific HCI course design. We were particularly interested to see if using user centered design (UCD) principles and participatory design (PD) techniques in our course design would contribute to a positive learning experience (just as applying these in interaction design would contribute to a better user experience). We discuss the results with reference to how successful the application of UCD and PD was in this study, whether it improved students' design knowledge and skills, and whether it improved the learning experience.

4.1 The usefulness and practical applicability of the design outcomes

The participatory course design exercise conducted in July yielded two sets of input from the students: six recommended syllabi designed in small groups and presented to the whole group (Figure 5) and individual topic ratings submitted by 36 students (Figure 4, July data). Analysis of these results against the background of the requirements of the ACM and IEEE, led the lecturer to the syllabus presented in Table 3. Three of the ten potential topics (social impact of technology, HCI and education, designing for special user groups) are part of the lecturer's fields of expertise but did not feature at all in the students' recommended syllabi. They were therefore excluded from the course. Obviously, being knowledgeable about the topics, the lecturer would have preferred to cover aspects of these, but she was committed to the democratic PD process. She did not promote or emphasise her fields of interest or expertise in her overview of all the possible topics.

Interaction design, eye tracking and data visualisation stood out in the students' preferences, so these were obvious topics to include. They remained in the top four in the October ratings. Since eye tracking would be taught as a usability evaluation technique, and usability/UX is an important aspect of interaction design, we also included Usability and UX in the syllabus. It received the fifth highest score in the July individual ratings, but in October moved up dramatically into second place. Clearly it was the correct decision to include this topic in the syllabus.

HCI for IT managers and BAs received a high rating from individual students in July (fourth highest) and was therefore also included. In the second rating it moved down to sixth position to below Usability and UX and Cognitive psychology. We may have to reconsider its inclusion in future.

Data visualisation was one of the favourites in the beginning of the course (third in the individual ratings and included by four of the six groups). It moved slightly down in the second rating but was still in fourth position.

These results and comparison of student preferences in the beginning and end of the course confirm the usefulness and applicability of the outcomes of the participatory course design.

4.2 Knowledge and skill acquisition

We measured knowledge and skill acquisition in two ways – firstly by looking at the results of student assessment and, secondly, by analysing student responses to the course evaluation (with specific focus on comments relating to knowledge and skill acquisition).

Students scored very high in the assignments with average assignment marks ranging from 63% to 80.4% (see table 5). This could be attributed to the fact that three of the five assignments were group or pair assignments and weaker students may have relied on stronger students. The average mark for the written examination was 66.2% and only two students failed the examination. The assessments are moderated by an expert external

examiner, and therefore we trust that the assessments are of an acceptable standard.

The feedback from students relating to knowledge acquisition conveys a general opinion that useful knowledge and skills were acquired. Sixteen of seventeen comments relating to "Usefulness of course for career" (see section 3.5.5) indicated that students gained worthwhile knowledge. The general positive user experience (discussed next in section 4.3) can also be regarded as indication that students felt they gained from the course.

4.3 Contribution to the learning experience

The learning experience is reflected in students' engagement, enjoyment and achievement during the course. As discussed in the previous section, high levels of achievements were obtained in the module assessments. Student engagement is evident in the good class attendance (Table 4), participation in group assignments and diligence in submission of assignments.

Enjoyment was expressed in the comments section of the Lecurer/Module evaluation and particular in the "General comments" section. Twenty-three of twenty-eight comments expressed enjoyment as discussed in detail in section 3.5.5.

Eight of 19 comments on the organisation of the module content expressed appreciation for the PD approach to decide on the syllabus.

4.4 Conclusions

Based on the above discussion of the results we can provide the following answer to the research question: The HCI design principles and techniques associated with UCD and PD can be applied successfully to the design of an HCI course and doing this will contribute to student engagement and a positive learning experience. With regard to achievement in the course, it is difficult to prove that the co-design by students contributed to their marks. The students in this course did particularly well. We believe that this can to some extent be attributed to the application of HCI principles in the design, but further research is necessary in this regard.

We also achieved the outcomes associated with PD: we followed a democratic course design process, improved the knowledge we needed to design the course and involved students in the decision-making process, all of which led to improved engagement.

5. FUTURE WORK

PD is an iterative process and this course design constituted one cycle. The course will be offered again in 2015 and we will continue the PD process with the new class. Specific questions that arose during the first iteration that we will address during the second cycle are:

Should we make changes to the syllabus based on the different evaluations of the course (e.g. should HCI for IT managers be replaced with Cognitive Psychology)?

Should the number of assignments be reduced?

Should we include less theory and more practical work in the lectures?

How can we balance the breadth vs. depth issue in the syllabus?

How should we handle group work so that all students make an equal contribution?

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Integrating Information Security into the IT Undergraduate Curriculum: A Case Study

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ABSTRACT

It is clear that information security is an area of vital concern, and that global societies are facing an increasing number of challenges related to security. Attacks on computer systems often succeed because people are not aware of the vulnerabilities of their systems as they lack information security knowledge. Therefore, Information Technology (IT) professionals should be made aware of and educated about information security in order to protect such systems. South African universities, however, do not have guidelines to ensure that essential information security aspects are included in the IT courses that are offered. This paper addresses the problem that the extent to which information security is currently integrated into the IT undergraduate qualification at the NMMU, School of ICT, is unknown. This has been addressed by means of a survey which included structured interviews of the IT lecturers supported by a questionnaire. The argument for integrating information security into the IT curriculum is based on a literature study.

Categories and Subject Descriptors

K.3.2 [**Computer and Information Science Education**]: Computer Science Education, Curriculum

General Terms

Security

Keywords

Information and Cyber Security Education, Information Technology Curriculum, Security Concepts, Case Study Research.

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1. INTRODUCTION

The interconnectedness of today's global society has made computer systems vulnerable to information security threats. Incidents related to the disclosure of confidential information, and the major growth in computer viruses is on the increase. Globally, there have already been numerous cases of theft and other economic crimes documented that involve a loss of a substantial amount of money per incident. The greatest threat to the benefits allowed by computers and the Internet is that of security concerns [13].

Information security can be defined as the protection of information and the critical characteristics thereof which are confidentiality, integrity and availability. This also includes the protection of the systems and hardware that use, store and transmit that information. It is further suggested that the protection of this information can be achieved through the application of policy; training, education and awareness programs; as well as technology [11].

The purpose of information security education should be to integrate all of the security skills and competencies of the various functional specialities into a common body of knowledge; to add a multi-disciplinary study of information security concepts, issues and principles (technological and social); and to produce information systems security specialists and professionals capable of vision and pro-active response [9].

Information Technology (IT) is a rapidly evolving career, involving professionals who are increasingly expected to play a key role in contributing towards the information security needs of organisations. It is therefore important that academic institutions offering IT qualifications address this requirement within their curricula. IT lecturers should bring an increased awareness of information security into the classroom to help students gain a better awareness of security implications [6]. This is an ongoing challenge for IT lecturers.

The Association for Computing Machinery (ACM) Special Interest Group for Information Technology Education (SIGITE) also regards Information Assurance and Security (IAS) as one of

the knowledge areas that should be defined as a pervasive theme and must therefore be addressed throughout the learning experience. Whereas a knowledge area represents a significant body of knowledge in a discipline, pervasive themes include topics that should permeate the IT curriculum since they are addressed across all knowledge areas. It is also stated that both students and lecturers need to be consistently aware of how these pervasive themes need to be integrated into the curriculum [2].

Topics relating to information security should include the five basic security services as defined by ISO/IEC 7498-2 [8], namely: identification and authentication; authorisation and access control; confidentiality; integrity and non-repudiation. Other topics relating to the availability of information, accountability and privacy are also important to consider. The ACM specifically highlights other key topics including cryptography, redundancy, intrusion detection, social engineering, denial of service, malware, etc. Although the ACM defines IAS both as a knowledge area and as a pervasive theme, there is little guidance provided with respect to assisting IT lecturers in integrating information security as a pervasive theme into their various modules [7]. The ACM [1] regards, IAS as a domain which is the set of controls and processes (which are both technical) and policy intended to protect and defend information and information systems by ensuring their confidentiality, integrity, and availability, and by providing for authentication and non-repudiation [1].

The primary aim of the research conducted as presented in this paper was to determine the extent to which information security is currently integrated into the IT undergraduate qualification at the NMMU, School of ICT. This paper presents the research methodology in Section 2 and highlights the importance of information security in the curriculum in Section 3. Section 4 provides a background to the case study, followed by a description of the questionnaire design in Section 5. While Section 6 presents the results and findings, Section 7 provides a detailed discussion highlighting key issues related to the research undertaken.

2. RESEARCH METHODOLOGY

The research methods used for this research included a literature study, case study research and argumentation.

A literature study was conducted to highlight the importance of information security and to understand the integration of information security within the IT curriculum. This literature study was also conducted in the field of Information Security education in general, and within the IT qualification curriculum using guidelines as suggested by the ACM.

Case study research according to Yin [14] was conducted at the NMMU, School of ICT to determine the extent to which information security and related information security concepts are currently integrated into the IT undergraduate curriculum. To support the case study research, a structured interview with the aid of a questionnaire was conducted. The participants of this study were the IT lecturers responsible for teaching various modules within the IT curriculum.

The main argument for this research is formed based on literature study findings and case study findings. The argument is that information security should be integrated into the IT curriculum as a pervasive theme as advocated by the ACM. However, prior to conducting this research, the extent to which this is currently done within the NMMU, School of ICT, IT undergraduate qualification was not known.

The following section addresses the importance of information security in the IT curriculum.

3. INFORMATION SECURITY IN THE IT CURRICULUM

What cannot be overemphasized in today's competitive business environment is the importance and value of information security education [4]. Wilson & Hash [12] state that the focus of information security education should be to develop people's ability and vision to perform complex multi-disciplinary activities and the necessary skills that are needed to further the information security profession and to keep pace with threats and technology changes [12]. The IT curriculum as recommended by the ACM acts as a guideline for any formal qualification in IT. According to the ACM [3], the core of the IT curriculum is the IT Body of Knowledge. There are 13 knowledge areas within the IT Body of Knowledge. Information Assurance and Security (IAS) is one of these knowledge areas and should therefore be included when designing an IT curriculum. In addition, Border and Holden [6] regard IAS as one of the knowledge areas which should be addressed as a pervasive theme.

A pervasive theme is described as those topics that should be 'considered essential, but that did not seem to belong in a single specific knowledge area or unit' [3]. These themes should, therefore, be woven into the curriculum by being addressed numerous times and in multiple classes [3]. However, according to Taylor and Azadegan [10], this is not generally the case as the majority of undergraduate computing students learn programming and design with little regard to security issues.

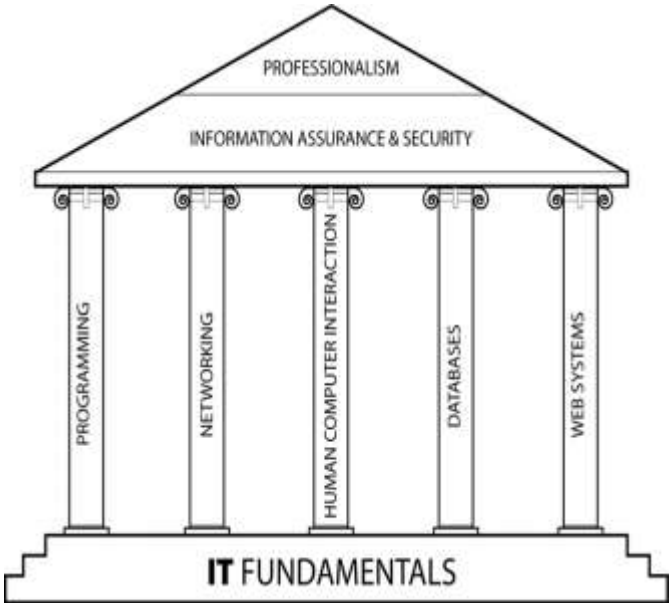

Figure 1: The IT Discipline [3]

From Figure 1, it is clear that IAS is an overarching knowledge area that impacts the total computer system and should therefore be integrated into all pillars of the IT discipline.

The ACM guidelines highlight various information assurance and security topics that should be addressed within the curriculum, together with related learning outcomes as shown in Table 1.

Table 1: Information Assurance and Security - Fundamental Concepts [1]

Topic	Learning Outcome
Nature of the threats	Describe the type of threats to data and information systems. [Knowledge]
Need for Information Assurance	Describe why processes and data need protection. [Knowledge]
Basic terminology (Confidentiality, Integrity and Availability)	Describe the context in which Confidentiality, Integrity and Availability are important to given processes and data [Application]
Threats and Vulnerabilities	Describe the major vulnerabilities present in systems today. [Knowledge] Define the fundamental motivations for intentional malicious exploitation of vulnerabilities. [Knowledge]

Despite the relevant topics and related learning outcomes, the ACM guidelines do not adequately address IAS as a pervasive theme; and no further guidance exists to assist IT lecturers in developing curricula to ensure that IAS is effectively integrated into the curriculum at undergraduate level [7].

4. BACKGROUND TO CASE STUDY

At the NMMU, School of ICT, the IT undergraduate qualification has three streams of specialism, namely: the IT Communication Networks stream, the IT Software Development stream and the IT Support Services stream. The IT qualification is a three year diploma course, after which students have the option to continue onto their fourth year which is also referred to as Bachelor of Technology (B Tech).

In the IT Support Services qualification there is a module dedicated to equipping the students with information security skills and knowledge. This module is taught to them at second year level. The same module is taught to IT Communication Networks students at third year level. For the IT Software Development qualification, however, no formal module addressing information security is offered to them at undergraduate level. This research therefore specifically focuses on the integration of information security into the IT Software Development qualification.

For all streams, Information Security is a module offered at fourth year level. Therefore, some students in the IT Software Development qualification will exit the university having never been exposed to information security, as they will not have continued to complete a fourth year qualification. Furthermore, at fourth year level the Information Security module is an elective, meaning it is not a compulsory module. This means that Information Security will only be taken by those students who study towards a fourth year qualification and by those who decide to take Information Security as a module.

Table 2 outlines the first year, second year and third year modules which form part of the curriculum of the National Diploma IT, Software Development (SD) qualification at the NMMU, School of ICT. For the purposes of this study, not all modules were considered, but only those which are core to the IT Software Development qualification.

Table 2: Key Software Development modules at the NMMU, School of ICT

Software Development		
1st Year	2nd Year	3rd Year
ONT1000	ONT2000	ONT3660
WIH1370	ITP2000	ONT3601
	PRT1000	WIH3602
	WIH2100	WIH3661
		PRT2110
		SGU1000

The codes for the modules represented in Table 2 are as follows: ONT1000 - Development Software 1;WIH1370 - Information

Systems 1; ONT2000 - Development Software 2; ITP2000 - Internet Programming 1; PRT1000 - Technical Programming 1; WIH2100 - Information Systems 2; ONT3660 - Project; ONT3601 - Development Software 3; WIH3602 - Information Systems 3; WIH3661 - Project Management; PRT2110 - Technical Programming 2; SGU1000 - Graphical User Interface Design 1.

Being core to the Software Development qualification, these modules were considered as being the ones with the most opportunity for the integration of information security concepts. They therefore formed the basis of the research conducted in order to determine the extent to which information security and related concepts are currently integrated into the IT Software Development curriculum.

The following section discusses the questionnaire design of the study conducted.

5. QUESTIONNAIRE DESIGN

The research study conducted at the NMMU, School of ICT, consisted of two approaches. The aim of Approach 1 was to determine the extent to which *information security (in general)* is integrated into the IT undergraduate diploma at the NMMU, School of ICT in the IT Software Development qualification. The aim of Approach 2, was to determine the extent to which *specific information security concepts* are integrated into the IT undergraduate diploma at the NMMU, School of ICT in the IT Software Development qualification.

For each of these two approaches, twelve participants were interviewed using a structured questionnaire to support the interview process. The participants were the IT lecturers of the modules as presented in Table 2. Each of the questionnaires underwent a pilot test to ensure correctness, conciseness and minimal ambiguity in the phrasing of the questions.

5.1 Approach 1

As mentioned, the aim of Approach 1 was to determine the extent to which *information security (in general)* is integrated into the IT Software Development curriculum at the NMMU, School of ICT.

The questionnaire for Approach 1 was designed using the security services and security aspects adapted from the ISO/IEC 7498-2 [8] standard, as well as those defined by Whitman and Mattord [11].

These security services are essential as they can be put into place to address a threat, namely: Identification and authentication, Authorisation/Access Control, Confidentiality, Integrity, and Non-repudiation/Non-denial. The additional security aspects as suggested by Whitman and Mattord [11] include: Availability, Accountability, and Privacy. These security aspects were also included in the questionnaire design for Approach 1.

The questionnaire for Approach 1 consisted of three sections:

- Section A addressed issues relating to risks associated with information security. The questions asked in this section were related to Information Assets, Threats, Vulnerabilities and Risk Analysis.
- Section B addressed security services associated with information security. The questions asked in this section related to Identification and Authentication, Authorisation/Access Control, Confidentiality, Integrity, Non-repudiation/Non-denial, Availability, and Privacy.
- Section C of the questionnaire addressed general issues related to information security aspects. The questions asked in this section related to secure user behaviour and security controls.

The questionnaire for Approach 1 consisted of three questions for each of the sections highlighted:

- Question 1: Is the particular security aspect/service currently being integrated?
- Question 2: Is the particular security aspect/service currently being assessed?
- Question 3: Are there any ideas for integrating the security aspect/service into the particular module?

There was additional space for comments to provide more qualitative data based on the discussions with each participant.

The results of this approach are discussed in Section 6.1.

5.2 Approach 2

As mentioned, the aim of Approach 2 was to determine the extent to which *specific information security concepts* are integrated into the IT Software Development curriculum at the NMMU, School of ICT.

Some of the information security concepts identified for the questionnaire were derived from an analysis of the IAS knowledge area and their related units within the ACM/IEEE Computer Society IT Curriculum Guidelines [3].

The information security concepts identified within the IAS knowledge included Attacks (e.g. Buffer overflows, Viruses, DOS); Authentication; Confidentiality, Integrity and Availability Concepts; Cryptography; Digital Forensics; Disaster Recovery; Ethical Issues in Computing (Privacy, Copyright); Information Backup and Recovery; Information States (Transmission, Storage, Processing); Intellectual Property; Intrusion Detection; Legal Issues in Computing (Hackers/Crackers); Secure Principles; Secure Software Development (SDLC); Secure-Coding; Security Awareness; Security Policies and Procedures; Security Standards (eg. ISO); and Security Threats and Vulnerabilities. All of these information security concepts were addressed within the questionnaire that supported the interviews with the various participants.

Further to this, the questionnaire aimed to determine at which level of Bloom's taxonomy each of the concepts should be addressed. The first and lowest level of Bloom's taxonomy is 'Knowledge'. Knowledge is the remembering of previously learned

material. This is where the student knows common terms and specific facts. The second level is 'Comprehension'. Comprehension is the ability to grasp the meaning of the material. The student should be able to explain or summarise the material, predict consequences or effects. Comprehension is the lowest level of understanding. The third level is 'Application'. Application is the ability to use the material that has been learned in new and concrete situations. With this the student should demonstrate the correct usage of methods and procedures, apply laws and principles to new situations, etc. This level of learning requires a higher level of understanding than that of comprehension. The 'Analysis' level is at the fourth level. Analysis is the ability to break down the material into its different component parts in order to understand its organizational structure. The student should be able to identify and analyse the relationships of the various parts. The 'Synthesis' level is the fifth level. This level is the second highest in the taxonomy and it deals with the ability to judge the value of something based on specified criteria and standards. The 'Evaluation' is the sixth level. This is the highest level in the taxonomy and it refers to the ability to put together various parts in order to formulate a plan or an idea that is new to the student [5].

The questionnaire for Approach 2 consisted of three questions for each of the security concepts highlighted:

- Question 1: How applicable is the specified IAS concept to the particular module?
- Question 2: Is the specified IAS concept currently being integrated within the particular module?
- Question 3: If the specified IAS concept is currently being integrated, at which level of Bloom's Taxonomy is this taking place?

There was additional space for comments to provide more qualitative data based on the discussions with each participant.

The results for this approach are discussed in Section 6.2.

The following section presents the results of the case study research conducted.

6. RESULTS AND FINDINGS

This section provides the results and findings of both Approach 1 and Approach 2 as described in Sections 5.1 and 5.2 respectively. After conducting the structured interviews, the results were carefully analysed.

6.1. Approach 1 Results and Findings

Section A addressed the issues relating to risks associated with information security. The questions asked in this Section were related to Information Assets, Threats, Vulnerabilities and Risk Analysis. Figure 2 depicts the results and findings of Section A of Approach 1's questionnaire.

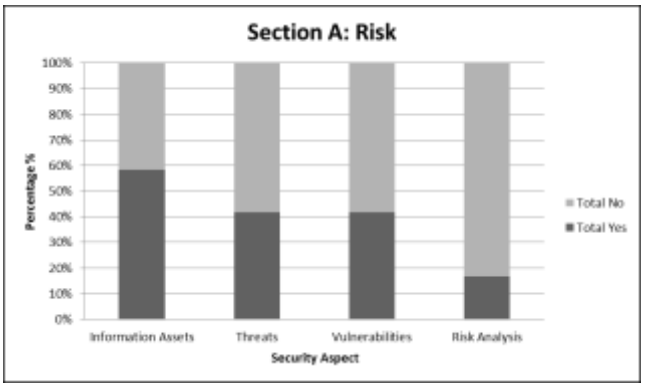

Figure 2: Information Security Risk Aspects (Overall)

As can be seen in Figure 2, 58% of the participants indicated that they do consider Information Assets within their modules (WIH1370, WIH2100, WIH3661, WIH3602, ONT2000, ONT3660, and PRT2110). Some of the reasons why it is not integrated into the rest of the modules are due to the lack of time to integrate it into the curriculum, and it not being relevant to some modules. Only 17% of the modules (WIH2100 and WIH3661) integrate Risk Analysis within their individual modules, while 42% of the modules (WIH1370, WIH2100, WIH3661, ONT3660 and PRT1000) address Threats. Similarly, only 42% of the modules (WIH1370, WIH3661, ONT3660, ONT3601 and PRT2110) address Vulnerabilities.

Section B addressed the various security services. As shown in Figure 3, 50% of the modules (ONT2000, ONT 3660, ONT3601, ITP2000, PRT1000 and PRT2110) are currently integrating Identification/Authentication. Similarly, 50% of the modules (WIH1370, WIH2100, WIH3602, ONT3660, ONT3601 and PRT2110) integrate Integrity into their modules whilst only 33.3% of the modules (WIH1370, WIH2100, ONT3660 and ITP2000) are integrating Confidentiality and 33.3% of the modules (WIH1370, WIH2100, ONT3660 and PRT2110) integrate Availability/Accountability.

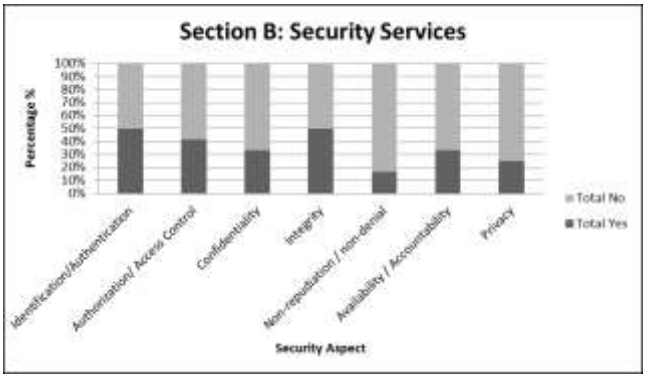

Figure 3: Security Services (Overall)

From these results it is clear that many of the security services are not currently being addressed by the existing modules. One of the main reasons why these security services are not being addressed is due to the fact that there is not enough time to integrate them into the current curriculum. In addition, most of the lecturers are

under the impression that they are being addressed by at least one of the other modules, while some of the lecturers believe that addressing information security services is not the purpose of their particular module. Although some of these security aspects in Section B are being addressed, most of them are not being assessed as they are being addressed informally. In the first year none of the modules in the curriculum address any issues surrounding Identification and Authentication. At second year level only 75% of the modules (ONT2000, ITP2000 and PRT1000) are currently integrating Identification and Authentication into the curriculum. At third year level 50% of the modules (ONT3660, SGU1000 and PRT2110) integrate Identification and Authentication into the curriculum.

The first year curriculum also has no modules which cover Authorisation / Access Control. The second year has two modules (WIH2100 and PRT1000), and at third year three modules (ONT3660, ONT3601 and PRT2110) educate students on Authorisation / Access Control. The third aspect being Confidentiality is only covered in one module of both the first year (WIH1370) and third year (ONT3660). Two modules (WIH2100 and ITP2000) of the second year curriculum integrate Confidentiality into the curriculum. Integrity is covered by three modules (WIH3602, ONT3660, and ONT3601) in the third year curriculum and only one module (WIH1370) of each the first year curriculum and the second year module that addresses information security Integrity is WIH2100.

Non-repudiation is only covered by two modules (ONT3601 and PRT2110) in the third year curriculum, but none of the first or second year curricula cover this security service. Availability is integrated into the first year by one module (WIH1370) and at second year curricula with also one module (WIH2110) covering Availability/Accountability. The third year curriculum has two modules (ONT3660 and PRT2110) which cover Availability/Accountability with respect to information security. The first year curriculum does not cover Privacy. The second year curriculum has one module (WIH2100) which deals with Privacy and the third year curriculum has two modules (ONT3660 and PRT2110) which integrate this security service into the curriculum.

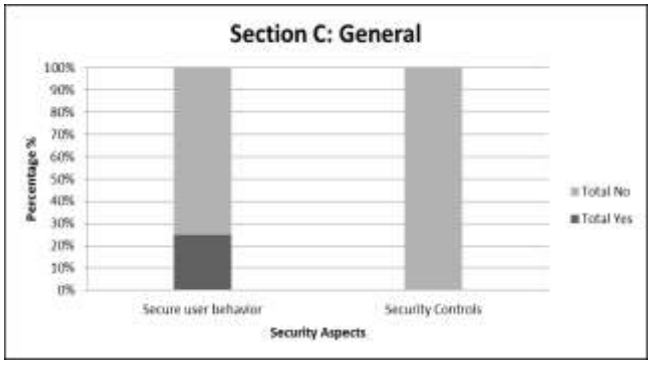

Figure 4: General Security Aspects (Overall)

Figure 4 shows the results and findings of Section C of the questionnaire. As shown in Figure 4 only 25% of the modules (WIH2100 and ONT3660) address Secure User Behaviour within their individual modules. Some of the lecturers who do not integrate Secure User Behaviour in their modules do not address it as they do not see it as applicable to their individual modules whereas some would consider integrating it if the information on how to integrate it was made available to them.

None of the modules address Security Controls within their modules. Many of the IT lecturers would consider integrating it if a suggestion on how information security can be integrated into their modules was made available.

6.2. Approach 2 Results and Findings

Figure 5 depicts the results and findings of Question 1 of Approach 2's questionnaire which aimed to determine how applicable the IAS concept is to the particular module.

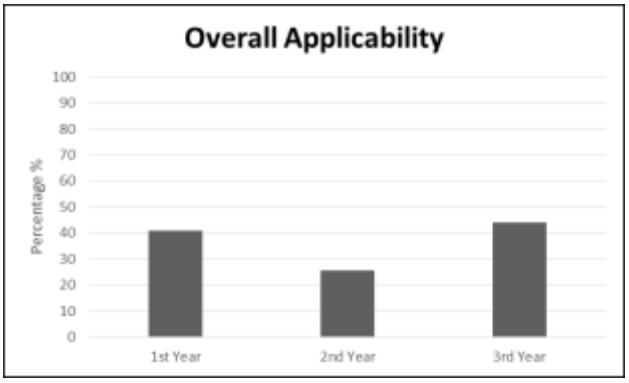

Figure 5: Overall applicability of information security concepts

At the first year of study the individual information security concepts with the highest percentage of applicability of 60% were Disaster Recovery; Ethical Issues in Computing (Privacy, Copyright); Information Backup and Recovery; Information States (Transmission, Storage, Processing); Secure Software Development (SDLC); and Secure Coding. As shown in Figure 5 the overall applicability level at first year for all the information security concepts was 41%. However, none of the IT modules are currently integrating these information security concepts as seen in Figure 6. There is a lack of evidence to suggest the reason for this. This is clearly a problem since many of these concepts are deemed to be applicable.

A further cause for concern is that none of the information security concepts at second year have an overall applicability level higher than 35%, although some of the information security concepts are being integrated. The information security concepts with an applicability level of 35% are Authentication; Confidentiality, Integrity and Availability (CIA) Concepts; Secure Software Development (SDLC); and Security Awareness. The average applicability of the information security concepts at second year is 25.75%; this can be seen in Figure 5. This result is even lower than that at first year level. These information security concepts are not being formally assessed in any of the modules, although they are briefly mentioned.

At third year the applicability levels vary, with the lowest at 20% and the highest being Information States (Transmission, Storage, and Processing) at 70%. While the applicability levels of the information security concepts increase at third year level, they were still very low when combined giving an overall applicability of 44.17% for the entire third year as depicted in Figure 5. It is not being formally assessed in any of the third year modules, but they are being mentioned. In some cases it was also stated that the text books do not even mention the information security concepts. This, however, does not provide a sufficient argument to not integrate these concepts into the various modules.

The year with the highest percentage applicability is the third year with an overall of 44.17%. The results suggest that the overall applicability of the information security concepts throughout the IT undergraduate software development qualification is not high at all being only at 36.97%.

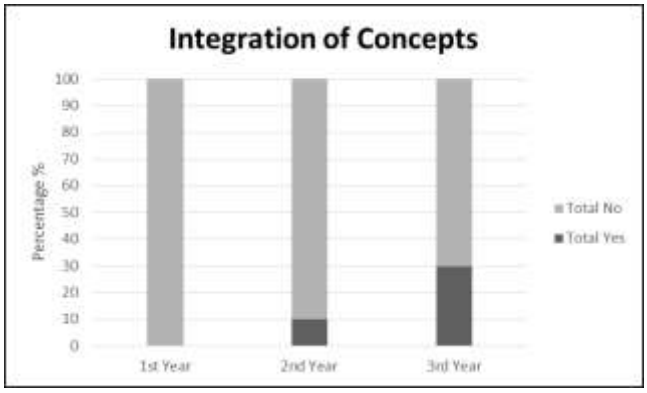

Figure 6: Overall integration of information security concepts

The results from the integration of the information security concepts further increases this concern because 87.78% responded in the negative over all three years. As shown in Figure 6, at first year level none of the modules are integrating any of the information security concepts identified in Section 5.2; at second year level, only 10% of the modules are integrating the information security concepts; and at third year level only 26.67%. This means that the majority of these information security concepts are not being integrated at all.

Some of these information security concepts are only mentioned during the semester or year. From the comments, the IT lecturers did not deem this as proper integration, but it can be a step in the right direction.

The results of the third question "If integrated, at which level of Bloom's Taxonomy would you consider this IAS concept to be?" found that more than half of the modules that answered "Yes" to integrating the various concepts, did it at the Application level. The others were at the Knowledge level with one at Comprehension level. This question is asked to see if the concept is integrated at the right level for the year of study. Most IT modules, no matter the year of study, require that the work should be applied. This is reassuring because at least the information security concepts that are integrated are at the appropriate level of Bloom's Taxonomy.

The results from this approach highlight important concerns with respect to the integration of information security concepts into the IT curriculum. The applicability throughout the years increases, except at the second year where it drops drastically. The integration of the information security concepts shows a slight improvement after each year. The reason for the general lack of integration of security concepts for most of the modules, gathered from the comments, is that the IT lecturers do not have enough time within the already overloaded curriculum. Some IT lecturers stated that although not formally being assessed, some of these concepts are however being mentioned at some stage during their module.

In addition, it was argued by many of the participants that information security is not the main objective of their module. In the first two years of the programming modules the focus is on programming aspects, although in the third year the focus is still on programming aspects, information security does start becoming important in the capstone project. With most other modules (eg. Information Systems), the focus is on the analysis and design of the system. Information security is only mentioned in these modules because it is perceived to be more important in the actual execution phase of the SDLC. However, it is important for IT professionals to realise that information security needs to be integrated into all phases of the SDLC and not as an add-on or afterthought.

The following section provides the discussion of the common comments from the twelve participants of the questionnaires.

7. DISCUSSION

As can be derived from the case study findings, less than 50% of the IT Software Development undergraduate diploma modules are currently integrating security aspects.

IAS is advocated as both a knowledge area as well as a pervasive theme by the ACM but little guidance is given to IT lecturers with respect to integrating information security into their different modules as a pervasive theme. This has also become evident in the comments given by the NMMU, School of ICT undergraduate lecturers during the interviews that were conducted. More guidance should therefore be given by the ACM or at national level as to how IAS can be integrated into the IT undergraduate diploma as a pervasive theme.

A cause for concern is the low percentages throughout the findings of this research. The reason for this outcome, according to the comments, is that many of the security services and information security concepts are not deemed to be applicable by the IT lecturers of the various modules. This is not reassuring as the ACM specifically states that these security services and associated information security concepts should be integrated into the IT curriculum.

The most common response from the twelve participants whom are the IT lecturers at the NMMU, School of ICT is that they do not have time to incorporate information security concepts and information security into their current curriculum. Most of the IT lecturers feel that information security is not the main focus of their module. Most of the IT lecturers are under the impression that there is a module in the Software Development qualification that teaches students about information security concepts and information security. There are however, lecturers that would consider the integration of information security concepts as well as information security into their curriculum, if practical guidelines were made available to them.

8. CONCLUSION

Information security should be integrated as a pervasive theme within the IT Curriculum. This is currently not being integrated as it should at the NMMU, School of ICT. The results from the case study prove this. The results can help identify the problem areas such as the "Secure Coding" concept and thus steps can be taken to improve the overall integration of such concepts.

Some of the comments from the questionnaires mentioned that it could be possible to cross or combine some of the modules for example: Development Software and Information Systems. The content of these modules are complimentary. By crossing or combining these modules they could work together towards a single purpose and by doing so these information security concepts could be integrated easier.

In future, similar research could be conducted in other academic institutions to determine whether there is a general trend with regards the poor integration of information security within undergraduate computer-related curricula. Further research could also consider the development of guidelines to assist lecturers in the integration of these concepts.

9. ACKNOWLEDGEMENTS

- This work is based on the research supported in part by the National Research Foundation of South Africa
- Gert Jacobus Visser for his contribution in collecting and analyzing Approach 2's data;
- The NMMU, School of ICT's Software Development IT lecturers for their involvement in this research project.

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Factors Affecting Students Changing Their Major to Information Systems

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ABSTRACT
The growing shortage of skills in information communication technology (ICT) is a major concern in Southern Africa and globally. ICT is critical to national development and business success and therefore the need for skills is growing. Yet despite high job availability and high starting salaries in ICT, students are not choosing to study in ICT fields. In this study we look at the Information Systems (IS) major where prior studies have found that misperceptions of the major exist in schools. Yet at university these misperceptions can be addressed. In this inductive and retroductive case study we identify the factors that students consider when changing their major to IS. The perceived value of IS is found to play a major role in students choosing the IS major. Events that trigger the process of changing major to IS include a loss of passion for previous major or difficulty in previous major as well as enjoyment of the introductory IS course. The paper argues for a generic first year for students as well as a focus on enjoyment and skills aligned to IS professional practice in introductory IS courses.

Categories and Subject Descriptors
H.0 [**Information Systems**]: General.

General Terms
Management, Human Factors.

Keywords
ICT skills, Information systems careers, IS major, computing curricula.

1. INTRODUCTION
South Africa faces a shortage of information communication technology (ICT) skills, outsourcing of some ICT skills and emigration of highly skilled ICT personnel [26]. These problems are not restricted to South Africa and are felt globally. Statistics produced by the United States (US) Department of Labour for 2010-2020 show that 73% of new United States Science, Technology, Engineering and Mathematics (STEM) jobs through 2020 will be in Computing [13]. Because of the constantly evolving ICT industry new ICT job roles are being introduced; such as IT Architect, Social Network Manager and Web Specialists [14]. As more ICT jobs are created, skills shortages will increase [34]. Increased student enrolments into computing disciplines could provide relief, but it seems that enrolments are not increasing sufficiently [23, 25, 29]. This combination of factors is contributing to a growing ICT skills shortage [5, 14, 17, 19]. This is particularly concerning as ICT is the platform on which most, if not all, businesses depend on to carry out daily operations [11].

There are many reasons why working in ICT is attractive. Firstly, ICT careers have one of the most competitive salaries in the world. IS majors received the highest average starting salary among the US Class of 2014 bachelor's degree in business [40] and computer science and IS are the only non-engineering majors among the top 10 highest paid bachelor's graduates [39]. Secondly, ICT careers are evolving as new ICT jobs types are created and new technologies are introduced and this gives ICT careers their competitive edge [12, 14]. A decline in computing discipline enrolments therefore raises concerns as to whether students are making adequate career choices and whether students are knowledgeable about the different computing careers available to them [26]. IS is one of the 5 computing disciplines and prior studies have shown that the IS discipline suffers from significant misperceptions in schools [46]. Yet these misperceptions can be addressed at University where students can reconsider their choice of major. This study therefore investigates factors influencing students changing their major to IS at university.

2. IS CAREER CHOICE LITERATURE
Factors affecting students choosing IS as a major can be divided into Social, Structural and Individual according to the Adya and Kaiser computing student career choice model [1]. Social factors include student perceptions concerning the IS major, jobs opportunities, career, importance and relevance in society. Structural factors represent institutional support available to

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students in pursuit of their careers. Structural factors include lecturer/career advisor, technology access and institutional educational arrangements [35]. For example, female students and students with low computer literacy have been found to rely on university structures as a source of learning more than male and experienced students [45].

Very little research has been done to investigate the structural factors impacting career/major choice [1]. Lotriet, Matthee and Alexander [35] researched one aspect of the Ayda and Kaiser [1] career choice model, namely, internet connectivity and its impact on computing majors. They criticised the career choice model as their findings showed that structural and individual factors are not independent.

Social Cognitive Career Theory (SCCT) shows how basic career interests develop over time and has been applied to career choices made by IS students by many authors [2, 6, 17, 27, 35]. SCCT gives the two dominant individual factors in career choice as self-efficacy and outcome expectations.

Factors that affect students choosing any computing degree and how the factors relate to students during their high school years have been researched [5, 6, 16, 17, 37, 46]. Yet, not much research has been conducted after students have completed their first year of University. Much of the research on perceptions is based on pupil misperceptions and lack of access to technology. Yet once students have completed first year at university and a mandatory computing course these misperceptions should have been addressed and lack of technology should no longer play a role. Therefore what are the other factors that students consider when choosing to major in Information Systems?

Previous researchers have argued that these factors are complex and inter-related and need in-depth exploration. Hence this research aimed to determine why students change their major to IS after their first year at university. The context was the University of Cape Town's commerce faculty where students irrespective of their major follow a mostly common first year and can change their major at the end of their first year in most cases without extending the length of their degree.

3. METHOD

A single interpretive case study was chosen for this research because it enabled a deep exploration into individuals and their behaviour [8]. The case chosen in this research was the Commerce Faculty at the University of Cape Town. Students have to choose a major when arriving, yet, with the exception of computer science and actuarial science, they have the freedom to change majors and only after the end of their first year does changing majors become restraining. For majors which include IS, Accounting, Economics, Finance, Marketing and Organisational Psychology the first year of studies is generic and is referred to as the "common first year". The common first year courses include Accounting, Economics, Business Law, Mathematics, Statistics, Evidence Based Management and IS.

The introductory first year IS course focuses on students understanding information systems within organisations as well as their broader impact. In addition students get introduced to computational thinking techniques used in software engineering; analyse data using Microsoft Excel; and design and implement simple applications using a programming language.

A list of 18 students who had transferred into IS during 2014 was obtained from the Student Records Office. The most common prior majors were Accounting (6 students) and Finance (3 students). The researcher sent an individual email to these students inviting them for an interview. Semi-structured interviews [38] were conducted with the 8 students who responded (Table 1). The research questions and themes from the literature formed the basis for the interview questions. A limitation to this study is that not all students invited responded and this could have introduced bias. The sample size of eight is deemed to be sufficient for qualitative analysis although more responses would have been preferred and theoretical saturation was not reached.

Inductive and retroductive approaches were used for the research. An inductive approach observes phenomena and develops a theory [22] while retroduction seeks to explain sequence of events by postulating and identifying mechanisms which are capable of producing them [20]. Thematic analysis was used to analyse the data inductively [10]. As part of the retroductive approach, students were also asked to describe the sequence of events that transpired before they changed their major. Some factors affecting students choosing IS as a major confirmed some of the prior theoretical models and therefore this research also had elements of deduction.

Table 1. List of research participants

Interview Code	Gender	Year they changed to IS	Previous Major
I1, I2, I8	Male	Second Year	Accounting
I3	Male	Third Year	Computer and Electrical Engineering
I4	Male	Third Year	Computer Science
I5	Male	Third Year	Accounting
I6	Female	Second Year	Actuarial Science
I7	Male	Third Year	Marketing

4. IS PERCEPTIONS FROM SCHOOLS STILL PREVALENT AT UNIVERSITY

The assumption made is that misperceptions of majors would have been resolved by the end of a student's first year at university and that students would have relatively equal access to technology provided by the university and have experienced improved computer efficacy by completing the introductory IS course. Yet students are reluctant to change majors and it became apparent in this research that factors which were prevalent in high school still affected interviewees. These factors were dominated by misperceptions of the value of IS and a lack of IS information.

4.1 A lack of IS Information

The comments by the students showed that they were not previously exposed to IS and hence this was why they did not choose IS. What was also mentioned was that IS was not mentioned by teachers and not advertised in high school recruitment.

> *"Teachers would tell people "CA are the way to go, it has the most money". IS wasn't really explained what it was about so I didn't really know what it was about" [I8].*
>
> *"I feel like a lot of people come from backgrounds like they only choose to do what they have been exposed to and have heard about. Too few people have heard about IS and so more people choose other B.Com. degrees" [I1].*
>
> *"I thought IS was computer science and very technical*" [I2]

4.2 Misperceptions of the value of IS

Students expressed that their view of IS was skewed based on the information they received prior to university and based on what they saw at school.

> *"I wanted to do IS when I was young but in my country (France) I was told that there were not enough jobs. I realise now after a few years that it is actually the opposite" [I7].*
>
> *I did accounting "because of my parents, accounting is very like prestigious, *inaudible*.....a lot of people go for accounting apparently it's well-paying" [I2].*

5. IS CAREER CHOICE FACTORS AT UNIVERSITY

Considering the reluctance to change majors, the factors that drove some students to change their major to Information Systems were considered. As part of the inductive analysis 11 core themes emerged. The number of empirical observations or text extracts which were counted for each theme are listed in the Table 2.

The relevant ranking of each theme was determined by the count of observations for the theme as well as the importance that interviewees gave to the theme. The retroductive analysis for each interview focused on the core sequence of events that led to a student changing their major to Information Systems. While a student might have referred to many themes only the dominant ones were selected. In the paragraph below and in Figure 1 the retroductive analysis for I1 is presented.

> *I1 chose his major because "accounting is very prestigious and a lot of people go for accounting apparently it's well-paying." Furthermore, his father was in the accounting profession, therefore he chose accounting because it was familiar to him. Before he arrived at university he had no information regarding IS. After he arrived at University, he found accounting boring and wanted to pursue his interest in Information Systems because he "enjoyed working on computers". He enjoyed the introductory course and was inspired by the success "stories and innovative IT stories pertaining to the relevance of IT". Afterwards he researched possible career paths and decided at the beginning of his second year to change to IS.*

Table 2. Result of inductive and retroductive analysis

Factor	Inductive analysis		Retroductive analysis							
	Count	Rank	I1	I2	I3	I4	I5	I6	I7	I8
loss of passion for previous major	11	2	1	1	1		1	1		1
difficulty with previous major	4	8							1	2
enjoyment of introductory IS course	8	5	2		2	1		2		
alternate options	6	6							2	
academic performance in introductory IS course	5	7			3	2		3	4	
Seeking IS information	9	4	5	2	5	4	2	4	3	3
risk and uncertainty in changing major	2	11		4			3			
perceived value of IS	15	1	4	3	4	3		5		
IS interest / preference	11	3	3			5				
restrictions on choice of major/courses	4	9						6		4
recruiter influence	3	10								5

This sequence of events leading to I1 changing his major to IS is also numbered in column I1 in Table 2. The same analysis was repeated for all interviewees and is presented in the relevant columns in Table 2 and is presented graphically in Figure 2. Dominant factors are in in bold font. Factors which triggered or started the process of changing major are referred to as trigger factors and are depicted in italicized font. Factors at the end of the process which preceded the event of actually changing major to IS are shown in shaded circles. In the following sections each theme will be discussed in the context of existing literature following their sequence in the retroductive analysis.

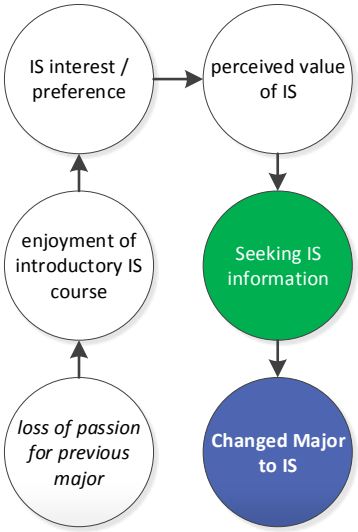

Figure 1. Retroductive analysis for I1

5.1 Loss of Passion for Previous Major

The second most dominant factor based on the number of empirical observations and the most dominant trigger factor was loss of passion for previous major. Students are reluctant to change their initial major and it seems that the dominant driver is a negative experience with their major as opposed to a positive experience with another potential major, 7 out of the 8 students who transferred into IS stated that the loss of passion for their previous major made them rethink their major. Quoting I5: *"I just lost the passion for it I guess, I didn't have the drive to study and continue with it"*. A student's passion in their major is said to be reflected in their educational and professional aspirations [41]. Research has indicated that students primarily lose interest because of a lack of mentors, role models, and career guidance [43]. In contrast students in this research found their previous major tedious and draining.

5.2 Difficulty with Previous Major

Difficulty with major was identified as a major factor contributing to students' changing major and was the trigger factor for one student. Students expressed that the requirements for their previous majors were too high to fulfil or they were just not coping academically. Difficulty with a major can be linked to students' learning styles, the approach to learning and orientations to studying and intellectual development [24]. Difficulty with major can cause students to reassess their academic standing and investigate steps to ensure that they are able to fulfil degree requirements. Sometimes it leads to changing degrees as is the case with the students who changed to IS quoted here: *"Also the requirements for actuarial sciences were high and economics was giving me a problem also" [I6]; "I was failing. IS was kind of a backup plan but at the same time I still think it's interesting." [I7].*

5.3 Enjoyment of Introductory IS Course

Enjoyment of the introductory IS course ranked fifth in the list of factors that led to students choosing IS as a major, it was a factor that was essential to the process and was the trigger factor for one student. It also appeared to directly influence academic performance in the introductory IS course. Some students passed really well and were even performing better on the introductory course than on their major and this increased their self-efficacy. Hence Enjoyment for the introductory course sparked interest in the IS major. Studies have shown that enjoyment of a major is an intrinsic value and has a direct influence on intention to study [3]. Intrinsic motivation refers to the pleasure and satisfaction gained from performing a behaviour [18]. Enjoyment is also based on the experience that students have had working with computers [15]. Quoting I1: *"I just wanted to do something that I can enjoy because I have experience doing things that are unenjoyable and you waste time at university as well and now to think about life… When I did IS 1 I really enjoyed that. I enjoyed the part where you just got use computers and you didn't have to write and accounting is just a drag. You have to do tutorials then you have to do the same thing over and over again" [IN01].*

Enjoyment of the first year introductory course is an important finding, students perceive that if they enjoy a course they would enjoy a career in that field.

5.4 Alternate options

Searching for alternate or secondary options was ranked 6th in the reasons why students choose IS as a major. It often followed from students struggling academically in their initial major. Career choice can be linked to available options because students chose careers that they have been exposed to and have self-efficacy [5, 6, 25]. Some students referred to IS as not their first choice but due to their performance in their first choice or due to curriculum constraints in terms of changing to their best choice, they chose it as their alternate option as quoted here:

> *"I was like I need courses and subjects and took up the next IS courses and kind of forced myself through it and started liking it and saw its value" [I3].*
>
> *"Mainly UCT with the concession (academic concession due to poor performance), I didn't really have a choice. It's a good thing; I think it was destiny (God-willing)" [I7].*

"and to transfer into engineering is too hard and it's not like I am saying IS is my second option…it just seemed more fitting what I want from IT" [I2].

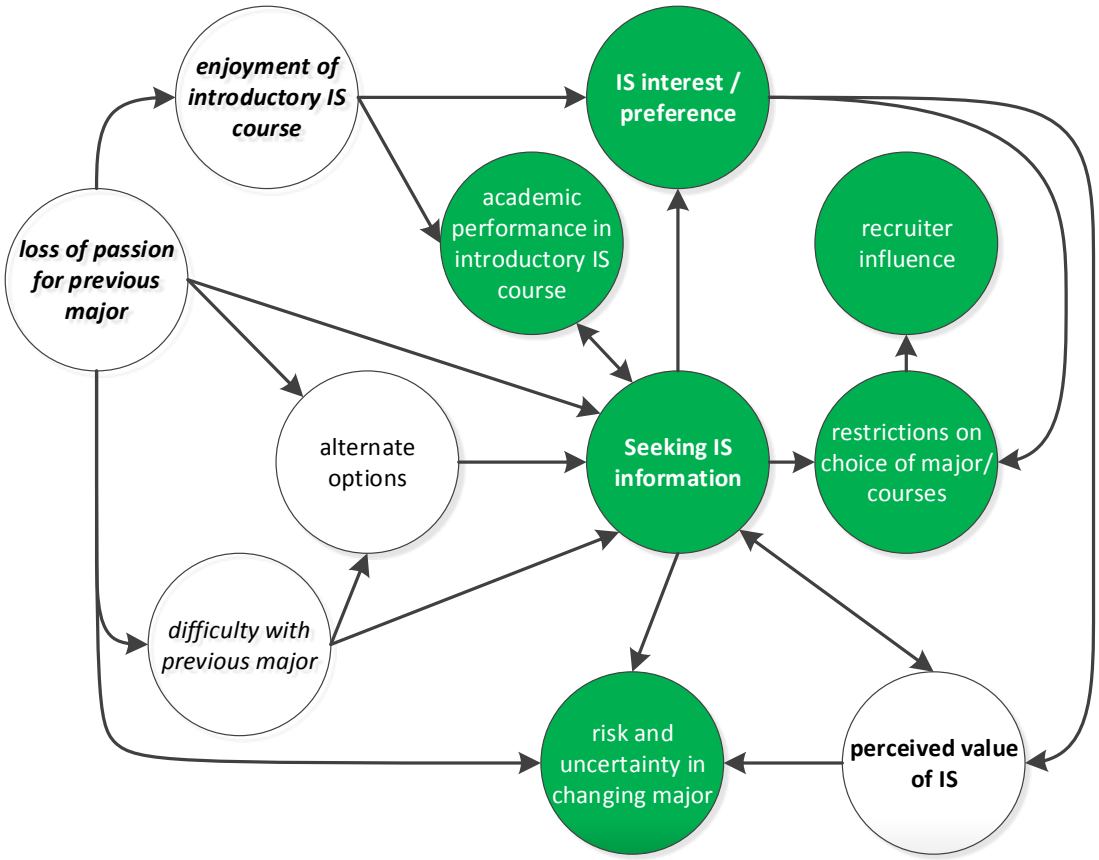

Figure 2 Sequence of factors affecting students changing to IS at university.

5.5 Academic Performance in introductory IS course

Students are more likely to develop interests in a computing major when they feel confident about their capabilities to succeed [2]. Self-efficacy has been identified as the main factor when choosing a major/career [5, 6, 7, 28, 30, 33, 35, 42]. Self-efficacy is heightened through academic performance and thus influences major choice [5, 7, 33, 42]. In this study the realisation that IS was a good option was through academic performance in the introductory course. This theme mostly followed enjoyment of the introductory IS course. Some students even found that they performed better in the introductory IS course than in their majors hence this was a core reason for choosing IS:

> *"I was top of class and I got medals at it" [I3].*
>
> *"In terms of my thinking, it worked better in CS than economics and accounting. I got 75%" [I6].*
>
> *"It was actually my best, I got 72%. That's why I wanted to do IS after marketing because I was getting 40s and 42% but I got 72% for IS" [I7].*

5.6 Seeking IS information

Seeking information about IS through personal research and sources of information regarding IS was a core factor and step in the process of converting to IS for all respondents. All students did some personal research to gain understanding of the IS major before changing majors. Sometimes it led to directly changing majors but it also led to unearthing risk and uncertainty or curriculum restrictions. It was ranked as the fourth most important factor. The sources of information regarding IS included the Faculty handbook, student advisors, IS graduates and recruiters. Some students chose to identify students who had changed to IS and engaged with them. It is worth noting that students chose to speak to people they deemed reliable and knowledgeable. Quoting three respondents:

> *"I had taken all of the courses in first year and second year which is very generic to any degree and then I was like ok, I made out all of the possible degrees I can do, so took a very objective point of view… my friends who studied IS. First they gave me a hands on what the projects are about, what they do in final year…I also talked to student advisors but they do it from a very like, this is how long it will take you not the context" [I2].*

> *"So I was looking at what I could take and what would interest me. Then I saw IS and CS in the booklet so I planned on changing to that and they said I could only take IS which was fine" [I8].*
>
> *"I knew one guy who did accounting with me then switched to IS. Yeah but mostly my research" [I5].*

Students are known to seek information before making a decision about selecting a major. Previous research focusses on the seeking process prior to university where sources of information regarding choice of major include family experiences of higher education and information sharing between students, families, schools and universities [36].

5.7 Risk and uncertainty in changing major

Students mentioned feelings of unease when deciding to change majors. I4 stated that even with all the information obtained regarding IS, he still felt unsure about his decision to change majors. I2 stated that he felt that it was a gamble to change majors and it was not a decision he took lightly when considering changing majors: *"Also like it was a bit of a gamble to change to something you don't know what it is, you are gambling quiet a lot changing a major, this is not like changing a course or dropping something" [I2].*

Students that register for courses expect the benefits of the course to exceed the costs of completing the course [9]. Students wanting to change majors faced this dilemma of evaluating whether it would be worth changing major or not. This is linked to the risk and uncertain feeling they felt because they were unsure of the outcomes.

5.8 Perceived value of IS

Perceived value of IS was ranked as the dominant factor and had the highest count of empirical observations. The perceived value of IS can be linked to the outcomes, such as future salary and high job prospects, that students hope to achieve at the end of their university years and in their career. Furthermore, students said they valued the team based work environment offered by IS jobs over "desk jobs" offered by their previous majors.

> *"I know there are a lot of job opportunities that are open for graduates"* [I6].
>
> *"I was inspired by success stories and like the richest people today...., everyone is doing something new and using IT"* [I1].
>
> *"I noticed I can make a lot of money if I go through this route and learn a lot about business" [I3].*
>
> *"The interest for IS came from the role that I could take with IS, that's the interest came not that I was good at computers or something… The role that it occupies in the world" [I4].*
>
> *"IS gave me knowledge of more teamwork based, project management just more collaboration" [I5].*

Inspiration by future outcomes/earnings has been documented in theory as Outcome Expectations. This has been recognised as a leading factor in SCCT [2, 6, 17, 19, 27, 35]. Job security and job availability refer to the ease with which students will obtain their first job after graduation and the availability of work throughout their careers [19]. Therefore long term prospects are very important when choosing a major. Students change majors because of the other attractions associated with the new major such as career possibilities, more interesting courses and available job openings in the field [32]. Previous research has referred to this as perceived usefulness of IS or perceived importance of IS skills [4, 5, 21, 25, 27].

5.9 IS interest / preference

Interest and preference for IS curricula was the third most dominant factor. All students said they chose IS because they had a preference and interest for the major and that they felt their skills were aligned with IS. Interest and preference for IS was different for each interviewee. What was consistent was that students wanted to work on computers and practical courses rather than theoretical courses.

> *"I have always been a technical person; I have enjoyed technology and information" [I5]. "I enjoyed the part where you just got use computers and you didn't have to write and accounting …you have to do tutorials then you have to do the same thing over and over again" [I1].*

The students wanted particular things out of IS. When choosing to change majors, they evaluated where their interests lied. Furthermore, most students in the study preferred more team work based work scenarios provided by IS. Students who choose computing majors have been shown to have a preference for an experimental style of learning rather than more structured approaches prevalent in non-computing majors [6]. Interest in IS curricula/major can be linked to students' attitudes towards a certain major which is unique and individualistic. Interest has been defined as an individual's psychological disposition or preference for certain activities and actions [47]. A preference linked to vocational choice is often attributed to self-efficacy for the subject [42]. In this research this experience is largely attributed to the introductory IS course.

5.10 Restrictions on choice of major/courses

Restrictions on choice of major relates to external influences such as faculty, bursars and course requirements. I6 stated *"it was going to be a lot of competition for a bursary."* Students who are given bursaries or financial aid that are linked to certain majors or have restricted time periods are also known to be less likely to transfer majors and hence financial aid reduces the flow of students between majors [31].

It is evident that some students lacked options when choosing their majors or even changing faculties. I8 expressed that: *"I wanted to study IS and computer science and they said I needed to study more maths to add to computer science so I decided to just study IS."* This quote relates to institutional arrangements which can allow or disallow a student to study certain majors due to pre-

requisite courses. Requirements in certain majors cause students to re-evaluate their academic standing and options when choosing a major. In this study, changing to IS had relatively few consequences and was aligned with the number of years they were taking for their previous major or it increased the length of the degree by a year at most. This is mostly because of the common first year. A previous study did identify factors such as prerequisite courses as hindrances to students pursuing their choice of major [44]. There has been a call for Universities to put education in the hands of students and have less restrictive curricula and transfer rules [44].

5.11 Recruiter influence

External recruiters at university career fairs can be seen as a motivating factor when changing majors. It is worth noting that there was not one particular theme relevant to how the recruiters were "selling" information systems to students. Some recruiters mentioned amazing job opportunities whilst some mentioned the work involved. Recruiters show students that there are job opportunities and that IS is very relevant. Recruiters are seen as a powerful influence because they are external and are perceived to have less bias than student advisors and lecturers.

> *"This IS guy who graduated in IS was recruiting people, not recruiting but advertising, talking about how he used to do something else but changed to IS and then he loved it because of the team projects and coding" [I8]. "I was talking to a lady working in Foschini groups who said there are a lot of job opportunities" [I6].*

6. CONCLUSION

Limited increases in computing discipline enrolments [29] are problematic when there is a simultaneous rise in demand for ICT professionals. Research has shown that the IS discipline is misunderstood by pupils in schools which contributes to low enrolment at university. In this case study in the Commerce faculty of UCT we researched students changing their major to Information Systems after their first year of university. We argue that after one year at university misperceptions from school should have been addressed. The inductive and retroductive analysis investigated the factors that influence the process of changing major to IS.

The perceived value of IS, such as future salary and high job prospects is found to play the dominant role in students changing to the IS major but is not the initial cause of them considering the change.

In this case, the triggering events for changing a major include a loss of passion or difficulty in a current major and enjoyment of an alternate introductory course. These factors can be generalised outside of this case setting and to other majors and hence this research is of theoretical relevance as it adds to the literature on factors impacting career choice in general. The experience of students in first year courses needs to be aligned with the experiences that professionals would face in their work environment and therefore students that would enjoy working in a particular professional would also enjoy the introductory course.

The identification of the dominant factors in this research is able to provide a practical guide to Universities. To increase enrolments in misunderstood majors, a generic first year for students is seen as critical and administrative or funding barriers to students changing their major need to be addressed.

To increase enrolments IS Departments can also make changes to the first year introductory IS course as follows. Firstly, the course content needs to focus on skills more aligned to IS professional practices so students are able to identify with the relevant work interests and preference; secondly the course needs to be made more enjoyable and thirdly IS information and the value of IS needs to be conveyed in this course.

However further research is still needed and this research only looks at a small facet of a broader field. What would be the unintended consequences of these suggested actions? What other factors can influence students changing their majors? How many students graduate in majors that they later regret? These are all questions worthy of future research.

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South African Alumni Perceptions of the Industry ICT Skills Requirements

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ABSTRACT

The Information and Communications Technology (ICT) skills shortage is affecting businesses globally and business managers often indicate that the ICT graduates they employ, lack the required ICT skill sets required by industry. Business managers and Alumni can provide an important contribution and feedback for assessing how effectively an institution's academic programs prepare its graduates for a successful career in the ICT industry. This study focused on ICT graduate's (Alumni) perceptions on the education and skill sets they received in their academic programs and the skill sets required in industry. The Alumni were asked if they received the appropriate education at university in the main four skill categories, namely software development, technical skills, business skills and soft skills. The importance of Software Development and Business skills were emphasised and new skills, including Business Analysis and Analytics, Business Process Modelling, Mobile Application Development and Internationalisation skills were highlighted. This research could assist and benefit Computer Science, Information Systems and other departments in teaching the required industry ICT skills.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer Science Education, Curriculum*.
K 6.1 Project and People Management – *Staffing*.

General Terms

Management, Human Factors.

Keywords

ICT skills shortage; Industry ICT graduate skill requirements.

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1. INTRODUCTION

Businesses are continuously required to adopt the use of new technologies in order to remain competitive and obtain strategic advantage. Presently, in South Africa, there is a demand for 829 800 highly skilled workers across a wide range of occupations and specifically 178 400 among professionals [4]. The professionals businesses require, include ICT professionals and graduates with the ICT skills to implement and maintain modern business applications. Businesses continually struggle to find qualified and suitably skilled ICT personnel [30; 6; 12] and find it difficult to recruit suitably qualified ICT graduates with the required technological as well as related business skills [23].

The Talent Shortage Survey 2014 from the Manpower Group South Africa indicated that ICT personnel are in the top 10 employee shortages [35]. The survey highlighted the importance of soft skills and specifically that businesses should partner with educational institutions to create curricula aligned to business ICT skill requirements. The limited number of people with the required ICT skill sets over the past years and the limited number of people choosing and enrolling for ICT careers is of major concern [15] and various initiatives have been initiated to deal with the ICT skills shortage problem [10, 24, 30].

The national and international ICT skills shortage, combined with the small number of ICT graduates graduating from tertiary institutions annually, makes it difficult for businesses to recruit suitably qualified graduates [23]. Research conducted in South Africa on the ICT graduate skills requirements indicated that the ICT skills taught at tertiary level do not always sufficiently prepare students for the requirements of industry [38].

A number of ICT related departments, such as Computer Science, Informatics, Information Systems, etc. at academic institutions have established closer relationships with industry. Industry Advisory Boards have been established at academic institutions in order to address the industry ICT graduate skills requirements and closer collaboration. Surveys have further been conducted by tertiary institutions to identify the industry ICT skills requirements [11; 36; 37]. Research by Marcarelli and Carter [36], for example found a potential disconnect in graduate's technological skills required by industry.

Academic departments have used surveys, mailing list, web-sites and social media, such as Facebook and LinkedIn to maintain

contact and acquire information from graduates (Alumni) working in industry [37; 46; 47]. Alumni tracking for program quality assurance using web-based systems have become an important activity at higher education institutions [43]. Alumni provide an important perspective and valuable contribution for the assessment of a department's academic programs. Academic programs have been restructured in response to international curricula [2; 3; 16] and recommendations by Professional Advisory Boards and Alumni [47].

This paper provides additional supporting evidence regarding industry ICT graduate skills requirements as indicated by Alumni. The results highlight the importance of mobile technology skills, social business skills and internationalisation skills. The research problem and research objectives are discussed in Section 2. Literature on the ICT industry skill requirements is discussed in Section 3. The ICT industry graduate skill requirements survey is presented in Section 4 and the survey results are presented in Section 5. The paper is concluded and proposals and future work are discussed in Section 6.

2. THE RESEARCH PROBLEM AND RESEARCH DESIGN

The research problem investigated in this study is based on the realisation that the contents of ICT graduate education in South Africa may not satisfy the requirements of industry and that ICT graduates (Alumni) could identify additional skills and knowledge required by industry [10; 37; 39; 46]. ICT graduates and business leaders indicate that tertiary institutions do not adequately:

- Educate and prepare students with the ICT skills required by industry;
- Focus on the academic and practical application of skills and problem solving abilities of graduates as required by industry;
- Align industry ICT requirements with academic programs;
- Teach new ICT skills and technologies timeously; and
- Liaise with industry and Alumni on industry ICT skills requirements.

The research question addressed in this study is: *What are the ICT Alumni perceptions of the ICT skills required by industry?*

The Alumni ICT skills questionnaire was compiled using a number of existing ICT skills questionnaires utilised in similar studies [1; 13; 20]. The NMMU Graduate ICT Skills questionnaire consists of the following sections:

1. Personal background information – starting position, current position, years in industry;
2. The graduate's present business background information – city, country, number of employees, recruitment strategies;
3. ICT skill requirements – current and future;
4. CS and IS curriculum; and
5. An evaluation of technical skills, soft skills, business skills and programming skills.

Sections 1 to 4 were open-ended questions and qualitative in nature. Section five obtained quantitative data and utilised a five point Likert scale (1=Strongly disagree to 5= Strongly agree) to determine perceptions of the importance of technical skills, soft skills, business skills and programming skills. A number of academics in the Department of Computing Sciences evaluated the questionnaire and suggested changes and improvements. A pilot study was conducted among six Alumni working at NMMU to validate the questionnaire initially.

The questionnaire was captured using the NMMU on-line survey tool. The next step in the research process was contacting Alumni who graduated and worked in industry. Social networks are increasingly being used and a large number of graduates are on social networks such as Facebook and LinkedIn. The Department of Computing Sciences created a profile on Facebook. The first call for participation was distributed via Facebook, LinkedIn and a limited alumni e-mail address list, known to the author and academic members of the department. The *snowball sampling technique* was utilised, requesting participants, through a referral network, to forward the survey request to other possible respondents. A total of 101 Alumni completed the survey. The quantitative results were statistically analysed and qualitative results were thematically analysed.

3. INDUSTRY ICT SKILL REQUIREMENTS

The ISETT SETA (Sector Education and Training Authority) survey indicate that there were 4,671 ICT occupation vacancies in 2007 [25; 42]. The figures of more recent studies indicated that the more realistic figure is 70,000 ICT vacancies [15; 19]. In the U.S.A., Canada, Europe, Great Britain and Australia, governments and professional ICT bodies have supported initiatives to address the worldwide ICT skills shortage [7; 17; 40; 9; 13]. Australia and the U.S.A. predicted skill shortages and skill shortage growth rates of 10% per annum [30; 34; 44]. The U.S.A. Department of Commerce's Office of Technology estimated that the U.S.A. would require more than a million new ICT professionals by 2005, making ICT the fastest growing industry in the country [6].

In 2007, the Information Technology Association of America (ITAA) identified the need to double the number of graduates in science, technology, engineering and mathematics over the next ten years to maintain ICT competitiveness in the United States [12]. Krakovsky [32] cited the U.S.A. Department of Labour's Bureau of Labour Statistics projection of 800, 000 to 1.5 million ICT positions required between 2010 and 2018. The 2011 report by Dice.com indicated a shortage of 83,000 professionals in the U.S.A. [30]. The projections further indicated that 7 out of the 28 fastest growing occupations were in computing with a predicted average growth rate of 48% by 2014 [45].

In South Africa, one aspect of the ICT skills debate currently focuses on the misalignment between ICT graduate skills requirements by industry and the graduate ICT skills competencies provided by tertiary and training institutions [23; 30]. The criticism of university graduates entering the job market is that they lack key skills required by business [15]. The reports

indicate a "disconnect between academia and business" and that graduates entering the job market are lacking skills required by business [15; 23] including technical skills [26]. Employers indicate that graduates are not "work ready" when they enter the job market and that graduates are not multi-skilled [23; 30].

The vacancies included positions such as Network and Systems Engineers, Business Analysts and Software Developers. The vacancies predicted for 2010 included positions such as Project Managers, ERP consultants and Mobile Developers [28]. The positions where major shortages are currently being experienced include Business Analysts, Software Developers and Testing and Quality Assurance Specialists [14; 30]. New technologies businesses require include Software as a Service (SaaS), mobile and cloud computing, social business, business analytics and project management [26; 23]. Business Process Management, Business Intelligence and Knowledge Management skills were highlighted in similar studies, while Infrastructure Management and Information Security were skill categories required in the future [30; 26].

The Accenture Study [1] indicates that a strong demand exists for ICT skills in the project -, process-; configuration- and change management areas. The Accenture study further revealed that there was a strong demand for ICT professionals with soft skills, such as business, communications and management skills [1]. The study further indicated that project management, presentation and communication skills were some of the most sought after capabilities which industry required from ICT professionals.

Gartner's 2008 CIO Priorities report indicated that Business Process Improvement was first in the Top 10 Business Priorities. Enterprise Applications (ERP) and Customer Relationship Management (CRM) were placed second in the list of the Top 10 Technology priorities [22]. Application development is continuously in demand, including programming skills such as Java, C# and VB [30]. Information Systems jobs have changed from software development to application development and systems integration and have become more diversified and generic [8; 21; 31; 43].

A number of researchers have defined and described ICT skill categories and have identified and classified ICT related skill sets over the years. Todd, et al. [48] compiled skill categories based on 1970 to 1990 data. Lee [33] extended the skill sets required by IT professionals to include data obtained in the early 2000s. Lee [33] identified new ICT skills requirements in the Architecture/Network skill category and skills relating to the Internet, specifically E-Commerce, security and process modelling.

Technical skills, business skills and humanistic job skills are most frequently referenced in academic and practitioner literature [23; 24]. Gallagher, et al. [20] indicate that in the continuous and fast changing ICT environment, businesses require IT professionals with a mix set of skills. Gallagher, et al. [20] concluded that basic knowledge of six skill-set categories (Table 1) should be included in ICT-related curricula. Graduates should have a basic knowledge of all skill categories identified. Businesses indicate that universities are not producing ICT graduates with the required levels of technical expertise to enable business growth and provide competitive advantage in modern business environments [26].

4. INDUSTRY ICT GRADUATE SKILLS REQUIREMENTS

The number of first year students enrolling into ICT related degree programs has been declining since 2001 [5]. The past four years however, a number of academic departments reported an increase in enrollment figures. The reasons for the initial decline are attributed to the limited number of scholars choosing to study ICT degree programs [15; 30]. This decline is attributed to the confusion over the variety of different degree programs, the limited knowledge about ICT career paths in industry and the perception that degree programs do not prepare students and equip students with the needed skills for careers in ICT [23; 10].

Merkofer and Murphy [38] indicate that fifty percent of the respondents who participated in their study maintained that "e-skills taught at tertiary level do not sufficiently prepare them for the expectations of their roles in employment". Respondents indicated that the practical application of the skills taught "was a significant missing component from tertiary training". The study further indicated the importance of soft skills, including time and leadership skills, project management and communication and negotiation skills.

Extensive research has been conducted on the ICT graduate skills requirements. Researchers have classified the ICT skill sets into different categories [5; 1; 10]. Gallagher, et al. [19] identified six skill-set categories (Table 1) and Aken and Michalisin [5] expanded on this and compiled a framework for the categorisation of ICT graduate skills (Table 2). Table 2 indicates the four main categories of skills, namely soft skills, business skills, technical skills and programming skills. Each category is divided into sub-categories. ICT graduates should be educated and gain experience in each sub-category. Table 2 formed the basis of this study.

Table 1: ICT Professional Skills mix.

Technical skills	**Non-Technical skills**
Fundamental Skills	***Project Management Skills***
• Programming, System Testing, Database Design, Operating Systems, Telecommunications	• Leadership, Planning, Budgeting, Integration, Risk
Operational Skills	***Problem/Opportunity Skills***
• Operations, IT services, Disaster Recovery, mainframe	• Business & industry knowledge, Business Process Design, Change Management
Essential Skills	***Relationship Skills***
• Systems Analysis & Design, IT Architectures	• User & Communications Management, Negotiation and Stakeholders Relationships

Table 2: Skills categorisation [5].

Soft Skills	Business Skills	Technical Skills	Programming Skills
Problem-solving skills	***Business processes***	***Software development***	***Current languages***
• Ability to Learn • Attention to Details • Business Problem Solving • Creativity • Critical thinking • General Problem Solving • Research skills • Working under pressure	• Accounting • Business Process Design/ Re-engineering • Contracting and legal • Finance • Marketing • Supply Chain • Management	• Agile Development • CASE Tools • Client-Server • Programming • SDLC • System Testing • Systems Analysis • Systems Design • User-Interface Design • Web-based Application Development	• .NET • AJAX • ASP • C/C++ • C# • ColdFusion • HTML/XHTML/DHTML • Java/J2EE/J2P • Perl • PHP • SQL • Visual Basic • XML
Interpersonal skills	***Management skills***	***Business applications***	
• Conflict Resolution • Interpersonal Relationships • Leadership • Self-esteem • Teamwork	• Change Management • Managing 3rd party providers • Outsourcing Management • User Relationship Management • Working Globally • Working with Virtual Teams	• Applying IT to Business Problems • Customer Relationship Management (CRM) • DSS/GDSS • Enterprise Resource Planning (ERP) • Operating Systems • Transaction Processing Systems • Web servers	***Legacy languages*** • Ada • COBOL • Smalltalk
Work ethic	***Project management***	***Information management***	
• Initiative/Motivation to work • Integrity/Honesty/ Ethics • Professional Ethics • Responsibility • Self-management • Time Management	• Project Management/ Planning/Budgeting/ Scheduling • Project Risk Management	• Data Mining • Data Warehousing • Database Administration • Electronic Data Interchange (EDI) • Online Analytical Processing (OLAP)	
Language skills	***Strategy skills***	***Hardware***	
• Oral & Written	• Business Intelligence • Business Strategy • Project Integration	• Business Continuity Planning (BCP) • IT Architecture/Standards • Network administration • Security • Voice/Data Telecom	

5. ICT ALUMNI SKILLS SURVEY

The *ICT Graduate Skills* survey (n=101) was completed by NMMU CS and IS graduates working in the ICT industry presently. The descriptive statistics on the graduate profiles and backgrounds are provided. The questionnaire was completed on-line and the request to participate was done via e-mail and using social networks (Facebook and LinkedIn). A five-point Likert scale was used in some questions. Standard biographical data such as gender and race were not included in the survey and the provision of names, surnames and contact details were optional.

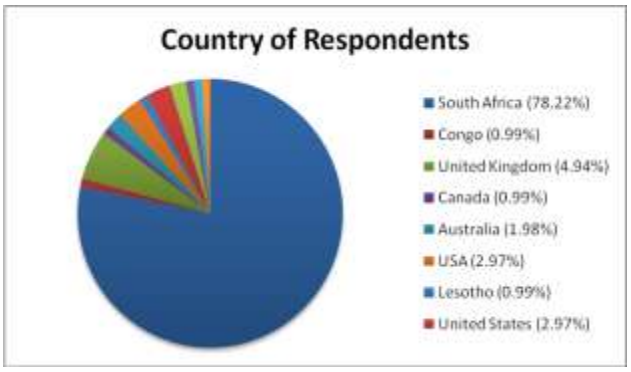

Figure 1: Current country ICT Alumni is living in.

Figure 1 shows that the graduates predominantly live in South Africa (78%), followed by the United Kingdom (5%) and U.S.A. (3%). The recruitment strategies employed by the businesses graduates are currently working for, include making use of recruitment agencies, graduate placement programs and internships, advertisements and informal and social networking platforms (Figure 2).

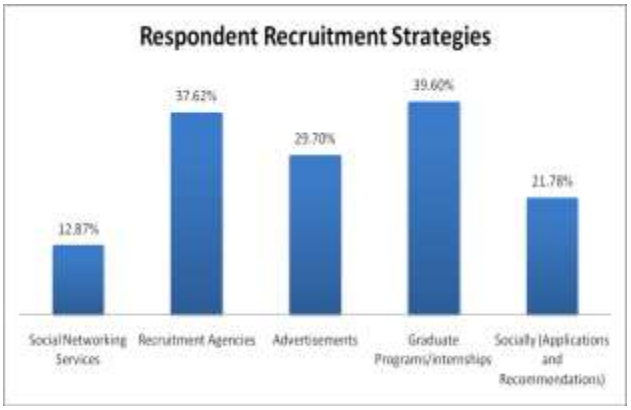

Figure 2: Recruitment strategies.

The graduates work in a number of industries (Figure 3), including finance, manufacturing, retail, telecommunications and healthcare. Twenty three percent indicated that they are working in other ICT-related industries. The graduates participating in the survey were on average 9 years in the ICT industry with minimum 2 months and maximum 30 years.

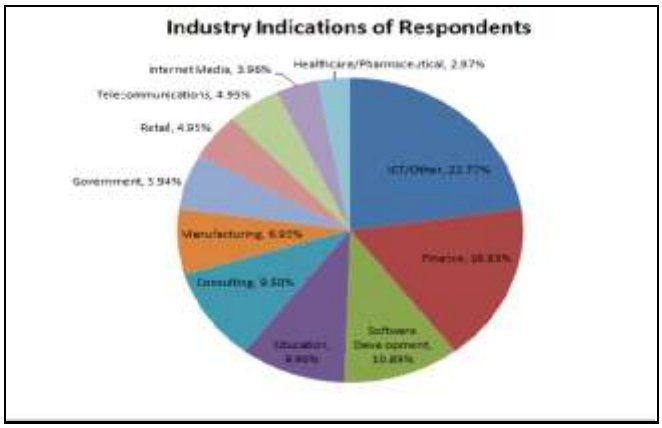

Figure 3: Industry indications of respondents.

Fifty six percent of the graduates indicated that the company they are presently working for are experiencing recruitment difficulties in obtaining suitably qualified ICT graduate skills. The responses to the open-ended question – *Does your company struggle to find suitably qualified graduates?* are recorded in Table 3. A number of respondents indicated that their company struggles to find "quality" graduates.

Table 3: Responses to open-ended question on difficulties recruiting ICT graduates.

Response: Does your company struggle to find suitably qualified graduates?
Not enough graduates. Quality graduates are hard to find.
Finding qualified and reliable people isn't easy.
We interview a number of candidates that don't meet the required skill levels.
Struggling to find people with right mix of IT experience and industry knowledge.
Difficult to find people that are really skilled / talented.
It's a SAP consulting firm, so they are always short of SAP skills.
It is not just technical skills, it is interpersonal skill as well.
Finding the right blend of qualification, experience and attitude is tough. Express themselves in English is important.

The predominant job titles of the ICT graduates are Software Engineer, Manager, Business Analyst, Software Architect, Project Manager, Consultant and Systems Analyst (Figure 4). The ICT job titles and job descriptions of all the ICT positions mentioned in Figure 4 can be defined as the "old standbys" and have been identified and specified in the computing discipline curriculum guidelines (CS2013, IS2010, IT2008).

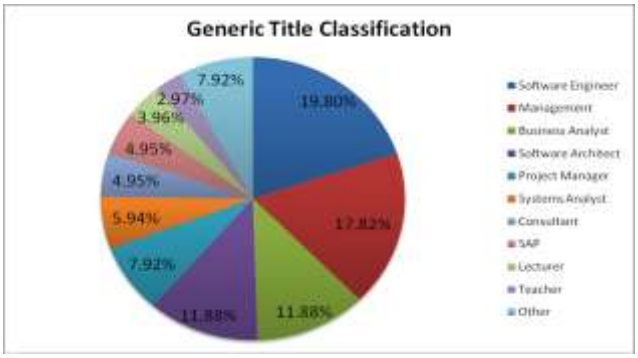

Figure 4: Present job title.

The ICT positions that ICT graduates were initially placed in at the start of the ICT career are indicated in Table 4. The ICT job positions were mostly at a junior level and the graduates indicated that the skills they acquired at university were adequate to fill junior positions. The ICT graduates further indicated their current job titles (Table 4) and the majority of the current positions are at a senior ICT or managerial level.

The results indicate that a large number of ICT graduates progress through an ICT career and advance into senior managerial levels and that their career path progressed in such a way that they acquired additional ICT skills to fulfil the senior ICT positions (Table 4). A number of graduates are presently Project Managers, Business Analysts and a small number of graduates were promoted to an IT manager, a Chief Information Officer (CIO) and a Chief Executive Officer (CEO) of businesses.

Selected responses to the open-ended question on present ICT skill requirements by the businesses where ICT graduates are presently employed are presented in Table 5. The responses cover a wide range of ICT job descriptions and include technical skill requirements. Networking, programming, business and mobile technology skills are in demand.

The technical skills required include Software Development and Information Management (Figure 5). The Business Application technical skills refer to specific technical skills in the use of ERP systems, such as sales and distribution, finance and manufacturing.

Selected responses identified by the author to the open-ended question on technical skill requirements specifically by the businesses where ICT graduates are presently employed are presented in Table 6. Programming skills, data modelling skills and SQL skills were mentioned, including vendor specific technical skills, for example IBM, Microsoft and Oracle skills.

The business skills requirements ICT graduates should possess are understanding of business processes, management skills, strategy skills, entrepreneurship and project and risk management skills (Figure 6). A number of respondents stressed the importance of entrepreneurship as they have started their own businesses.

Table 4: ICT graduates career starting job titles and current job titles.

Starting Title	*Current Title*
Analyst Programmer	Senior Project Manager
Innovation Architect	Usability Team Leader
Graduate Trainee	Product Development Manager
Software Analyst	Business Analyst / Project Manager
Programmer	Business Analyst
Analyst Developer	Architect Developer
Junior Programmer	IT Manager, Development Manager
Analyst Programmer	Systems Analyst/ Business Analyst
.Net Developer	Software Engineer
Junior programmer	Software Architect, Solutions Engineer
Systems Developer	Systems Developer
Developer	Chief Technology Officer
Graduate Trainee Programmer	Senior Software Architect
Programmer Analyst	Information Services Manager
Programmer	GM New business Development
.Net developer	Senior developer and BA
Programmer	ICT Project Manager, IT Manager
Developer	Business Analyst
Graduate Trainee	Integration Manager - BPM
Analyst	SAP BW Consultant
Programmer	CEO

Table 5: Responses to the open-ended question on present ICT skill requirements.

Which ICT skills does your company presently require?
System's Analysis, Quality Assurance, .Net Development, SQL. Mobile technologies. Web developers.
Developers, analysts, Project managers, QA, Architects.
SQL, Data analysis, business analysis and integration, data modelling, enterprise data architecture, data warehousing, MDM, data quality skills.
Business analysts, System Analysts and software developers.
ASP.Net SQL Silverlight WCF Windows Forms Applications Windows Services Java JQuery, JSON Crystal Reporting.
Technical Business Analysts, .Net Developers.
Data Analysts; System Architects; Network Specialists; PMO's.
ASP.NET, Php, C#, knowledge of Ajax.
HCI, mobile developers, .Net, Java, Python.

Table 6: Responses to open-ended question on technical skill requirements.

What are your company's ICT graduate technical skill requirements?
Strong programming skills (especially distributed and concurrent applications). SQL programming.
MS Office, software engineering, information management.
Programmers; content writers; web writers; usability people; project managers; technically strong people - knowing latest technologies - able to advise; web designers; Information architects; Solution architects; Content strategists.
Business analysts, system analysis and design, TOGAF, project management. SQL programming.

Figure 5: ICT technical skills required from ICT graduates.

Figure 6: Business skills required from ICT graduates.

The programming skill requirement includes SQL, .Net, Ajax and ASP followed by C# and web based programming and scripting languages (Figure 7). A limited number of companies required legacy programming language skills. The section of the questionnaire requesting graduates to evaluate soft skill requirements was divided into four sub-sections: Problem solving abilities, interpersonal skills, work ethic and language abilities. The following figures address each sub-section separately.

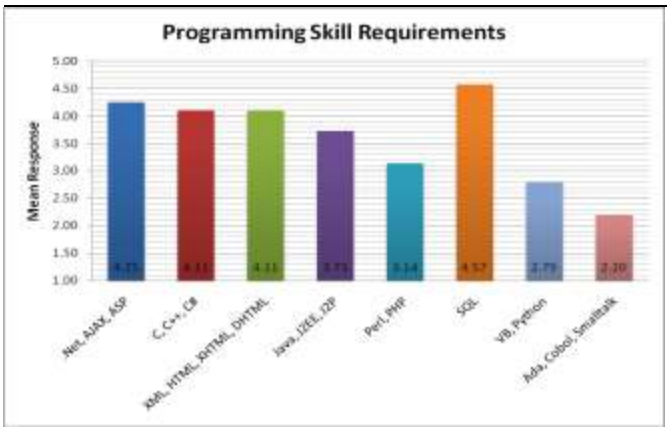

Figure 7: Programming skill requirements.

Figure 8 indicates that the graduates rated most items above a mean score of 4, indicating that all of the problem solving skills are very important. The ability to learn, problem solving, attention to detail and working under pressure were considered very important problem solving skills.

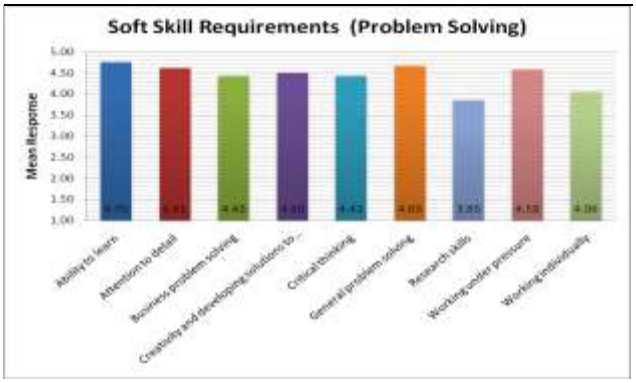

Figure 8: Soft skill requirements (Problem solving).

The interpersonal skills identified in this survey included team work, life-long learning and interpersonal relationships (Figure 9). The questionnaire did not include a section on internationalisation skills and this should be included in future studies.

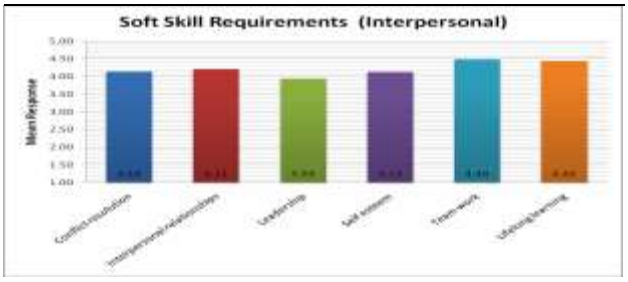

Figure 9: Soft skill requirements (Interpersonal).

The soft skills relating to work ethic were all highly ranked with a mean score above 4.5, meaning very important (Figure 10). Responsibility, motivation, ethics, responsibility and time management were identified as important soft skills graduates should possess. Soft skills identified relating to language and

communication skills included oral and written communication, presentation and questioning skills (Figure 11).

Figure 10: Soft skill requirements (Work ethic).

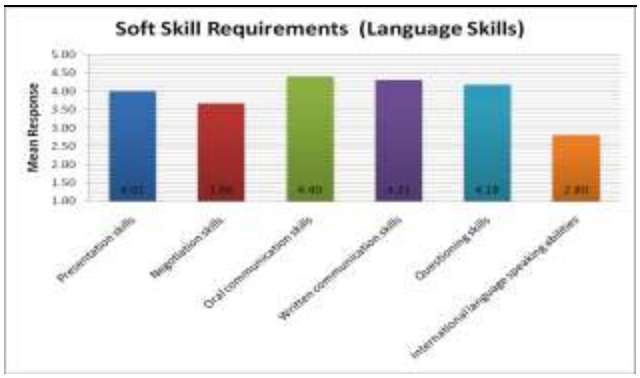

Figure 11: Soft skill requirements (Language skills).

Responses to the open-ended question on present ICT graduate interpersonal/soft skill requirements are listed in Table 7. The graduates provided a positive response to the question relating to soft skills and indicated a wide range of soft skill requirements. Communication, leadership, presentation, team work, self - motivation, self-learning and problem solving skills were mentioned by the majority of respondents.

Selected responses to the open-ended question on future ICT skill requirements by the businesses where ICT graduates are presently employed are presented in Table 8. Business Intelligence, security, mobile devices (Android and Iphone) and SQL skills were mentioned by a number of respondents.

In order to identify the most important skills, the results were statistically analysed and the items used in the survey were ranked (Table 9). Question 10 in the survey, namely soft skills–work ethic, was rated the highest, followed by problem solving abilities, technical skills, language abilities, business skills and programming skills. The first two items Soft skills–work ethic, Soft skills–problem solving, were rated statistically as *very important* (lower limit of 95% confidence interval > 4.20). The remaining six items were rated *important* (lower limit of 95% confidence interval > 3.4 and < 4.20).

Table 7: Responses to open-ended question on interpersonal soft skill requirements.

What are your company's ICT graduate interpersonal/soft skill requirements?
Strong team focus, good team communication skills.
Stakeholder management, presentation skills, core consultancy skills, business analysis, solution structuring, project management.
Problem solving, team work and self- motivation.
Good communication skills (verbal and written). Self-confidence. Ability to work in teams.
Presentations to business, preparing documentation, working in teams, managing people and expectations.
Easy going, presentable, confident, well spoken, hunger to learn, not afraid to go the extra mile.
Good communication skills, ability to organise people to get a task done, must take ownership of tasks.
Interpersonal skills, Team spirit, Social grace, Business etiquette and behavioural traits such as attitude, motivation and time management.
Self-learning, problem solving, handling customer expectations, working in distributed teams.
The ability to communicate things clearly and simply. The ability to learn `on-the-fly`.
1. Problem Solving 2. Communication 3. Documentation 4. Report Writing 5. Listening 6. Time Management.
Listening skills, Time management, Pressure Management, Relationship management.

Table 8: Responses to open-ended question on future ICT skill requirements.

Which ICT skills would your company require in the future?
Business Intelligence specialists. Big Data Scientists.
Developers, network engineers, server engineers, project management, sales and marketing.
Sharepoint, Business Intelligence (mdx, data cubes).
Mobile Devs especially in windows mobile, Android and Iphone development. We may branch in the Blackberry environment too.
Mobile development.
Web development in .NET (C#, Silverlight, etc.), database development (MySQL, SQL Server, etc.), and C++ multimedia (video/audio) programming.

Table 9: Scores ranked.

Item	Rank	n	Mean	SD	95% Confidence Interval	
					Low	High
Q10-Soft-WorkEthic	1	101	4.60	0.64	4.47	4.72
Q08-Soft-ProbSolv	2	101	4.43	0.59	4.32	4.55
Soft-All	3	101	4.29	0.54	4.18	4.39
Q09-Soft-IntPers	4	101	4.22	0.60	4.11	4.34
Q05-ICT Technical	5	101	4.04	0.70	3.90	4.17
Q11-Soft-Language	6	101	3.89	0.63	3.77	4.02
Q06-Business	6	101	3.85	0.79	3.69	4.00
Q07-Programming	7	101	3.61	0.56	3.50	3.72
>3.4 High and important > 4.2 very important						

In Table 10, Calitz identified the existing skills required from ICT graduates (highlighted in Yellow) and the new skills (highlighted in Green) required by industry [11]. The asterisk * indicates that the majority of respondents identified this skill. In addition, the ICT Alumni skills identified in this study is highlighted by a graduate symbol  .

The ICT Alumni that completed the survey indicated that current students graduating require skills across all four skill categories, namely soft skills, business skills, technical skills and to a lesser extent programming skills. The soft skills Alumni identified included problem-solving skills, interpersonal skills, work ethic and communication skills (Table 10). The business skills included the understanding of business processes, the modelling of business processes, project management and strategy skills. Internationalisation skills were unfortunately not included in the survey.

Graduates did however indicate the importance of entrepreneurship skills. The technical skills included software development skills, business applications, including ERP skills and information management. The programming skills highlighted the importance of SQL, .Net, C# and web based scripting languages.

The ICT Alumni Survey, from a business perspective, highlighted an important business skill, namely *Entrepreneurship*. In a country, such as South Africa, with high unemployment statistics, entrepreneurship is encouraged at all levels in society to stimulate economic growth and job creation. A number of ICT graduates from the Department of Computing Sciences over the past decades have started their own ICT businesses. Anecdotal evidence observed by academics in the Department of Computing Sciences indicate that a small number of graduates every year become self-employed and start ICT businesses and in some cases are supported by venture capital.

6. CONCLUSIONS

Obtaining input from Alumni on the quality and relevance of their education can provide a department with valuable information and assist with continuous improvement and self-evaluation. Departments should gather information from all key stakeholders regarding the effectiveness and quality of their academic program and services [37]. Alumni surveys can provide information relating to academic programs quality and relevance, experiences, participation in institutional activities and specifically employment success, i.e. finding work.

ICT businesses in South Africa have indicated that they find it difficult to recruit ICT graduates and acquire the required ICT skills [11]. Industry requires ICT graduates with multi-skill sets which include in-depth technical skills, business skills and the ability to use commercial technologies and software [26]. Research indicates that ICT graduates are generally not multi-skilled and that tertiary institutions do not timeously introduce new courses [15, 23; 10]. In this study the framework compiled by Aken and Michalisin [5] for the classification of ICT graduate skills (Table 2) was extended (Table 10).

The ICT Alumni identified skill requirements in all four skill categories; namely programming, technical skills, business skills and soft skills. The results confirm the ITWeb [28] and Gartner [22] research findings and identified the importance of Business Intelligence and Process Management Skills. The results further confirm present ICT positions and skill requirements [23], including Business Analysts, Software Developers, Software Testers and ICT skills including Business Intelligence, process modeling and mobile technology skills. Social networking skills were increasingly being identified as essential skills required from ICT graduates, including cloud computing, mobile computing and confirms other recent reports [27; 29].

ICT graduate multi-skilled qualifications were in higher demand than certified and diploma qualifications which supports the JCSE/ITWeb [30] survey results. The results of this study confirmed Harris's [23] statement that businesses require ICT personnel that "straddle the worlds of business and technology". Closer collaboration between universities and industry was advised, including internships, industry visits and the creation of incubators at CS/IS departments.

Alumni working in international organisations indicated that knowledge of Global Software Development (GSD) is an important skill, which allows businesses to take advantage of a skilled workforce across various time zones, specifically working with different cultures. The Alumni indicated that they work with project team members that are located at different sites, in different time zones, forming virtual teams and utilising a variety of collaborative tools for interaction. Graduates working in these teams need to be trained to deal with people with different customs, languages, beliefs, skills and interaction methods [41]. Education programs, such as the Open Ended Group Projects [18] have been developed to address the skills required to work in international teams.

Tertiary institutions need to take cognisance of future skill requirements and ensure that the curriculum addresses the skills shortages. The results are of specific importance to academic departments and the results could be used to address the ICT graduate skills gap and industry requirements. The findings from this study are of particular importance to all universities in South

Table 10: Graduate ICT skills categorisation framework.

Soft Skills	***Business Skills***	***Technical Skills***	***Programming Skills***
Problem-solving skills • Ability to Learn • Attention to Detail • Business Problem Solving • Creativity • Critical thinking • General Problem Solving* • Research skills • Working under pressure • Logical thinking *Interpersonal skills* • Conflict Resolution • Interpersonal Relationships • Leadership • Self-esteem • Teamwork *Work ethic* • Initiative/Motivation to work • Integrity/Honesty/ Ethics • Professional Ethics • Responsibility • Self management • Self development • Time Management • Continued willingness to learn *Language skills* • Negotiation Skills • Oral Communications • Questioning skills • Written Communications • Presentation skills • Human Interaction	*Business processes* • Accounting • Business Process Design/ Re-engineering • Contracting and legal • Finance • Marketing • Supply Chain • Management • Business Process Modelling* *Management skills* • Change Management • Managing 3rd party providers • Outsourcing Management • User Relationship Management *Internationalisation skills* • Working Globally • Working in Virtual Teams • International language and cultural skills • Customs and belief skills • Distributed members and groupware skills *Project management* • Project Management/ Planning/Budgeting/ Scheduling • Project Risk Management *Strategy skills* • Business Intelligence • Business Strategy • Project Integration *Entrepreneurship skills* • Opportunity • Innovation	*Software development* • Agile/RAD Development • CASE Tools • Client-Server • Programming • SDLC • System Testing • Systems Anal & Design • User-Interface Design • Web-based Application Development • Data modelling skills • Requirements elicitation, specifications writing skills • Source control and version control • Testing and quality assurance* • Compiler knowledge • Patterns *Business applications* • Applying IT to Business Problems • Customer Relationship Management (CRM) • DSS/GDSS • Enterprise Resource Planning (ERP) * • Operating Systems • TPS (Trans Proc Systems) • Web servers/data centric websites • Working with large databases* *Information management* • *Data Mining* • *Data Warehousing* • *Database Administration* • *Electronic Data Interchange (EDI)* • *Online Analytical Processing (OLAP)* • *Database skills** *Hardware* • Business Continuity Planning (BCP) • IT Architecture/Standards • Network administration • Security • Voice/Data Telecom	*Current languages* • .NET • AJAX • ASP • C/C++ • C# • ColdFusion • HTML/XHTML/DHTML • Java/J2EE/J2P • Perl • PHP • SQL and SQL Server* • Visual Basic • XML • Silverlight • Mobile Apps development *Legacy languages* • Ada • COBOL • Smalltalk

Africa wanting to address the industry ICT skill requirements. The findings complement the findings of the Accenture report [1] and support the results of research conducted in the field of ICT skills shortage studies in South Africa.

This study has provided the foundation for continuous Alumni feedback and stakeholder engagement. Closer university and Alumni/industry collaboration and liaison are required for academic program quality assurance. A significant finding is that most Alumni participating in this survey indicated that the South African higher education system cannot fully provide the ICT skills requirements currently needed by industry. Future research will include extending this study to include more recently graduated Alumni and researching future ICT skills requirements.

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Attitudes Towards Computer Usage as Predictors of the Classroom Integration of ICT at a Rural South African University

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ABSTRACT
The aim of this research was to determine whether attitudes towards computer usage predict information and communication technology (ICT) integration in the classroom. The empirical study was supported by literature related to ICT integration in the classroom. The researcher followed a quantitative inferential research design to investigate the possible relationship between attitudes towards computer usage and ICT integration in the classroom. An adapted questionnaire was administered to all academic staff at a rural campus of a South African university during the 2011-2013 academic years. A total of one hundred academic staff participated in the study. Descriptive and inferential analyses were used to assess the relationship between attitudes towards computer usage and ICT integration in the classroom. The results of the study did not show a significant relationship between computer anxiety and attitudes towards computer usage and ICT integration, but did indicate a moderate relationship between computer attributes, cultural perception and ICT integration. Computer competence was seen as the most influencing factor affecting ICT use in the classroom. Based on the findings, it is recommended that effective institutional support is needed in terms of providing opportunities to academic staff to master adequate skills and knowledge not only about computers but also about ICT use in teaching and learning.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: Computer Uses in Education

General Terms
Human Factors

Keywords
Academic Staff, ICT integration, Quantitative Research, South Africa Higher Institution

1. INTRODUCTION
New technologies are changing the way we live, work and learn, and transforming many aspects of social, educational and economic organization in ways we could have hardly imagined less than two decades ago. This is partly due to rapid advances in information and communication technology (ICT) (Adesida, 2008).

Higher education institutions (HEIs) are also affected by the penetrating influence of ICT (Ololube, 2006). Undoubtedly, ICT has impacted the quality and quantity of teaching, learning, and research (Ololube, Ubogu and Egbezor, 2007). It offers many ways of improving teaching and learning in the classroom and university administration and provides opportunities for students whose choices may be limited due to lifestyle and life commitments and who are subsequently unable to attend classes and to discuss class work with lecturers and colleagues. ICT makes it easier to register students, keep and retrieve student records electronically (rather than manually), process and store marks, enable students to submit assignments, communicate with lecturers at any time, and also maintain contact easily with their classmates.

Although ICT is one of the most significant tools in education, wide disparities exist in its adoption and use within and between institutions (Bingimlas, 2009). Despite ICT's ability to act as a tool for change, the fact that this divide (within and between institutions) still exists will hold back educational development that is needed (Informa Media and Telecom, 2010).

Hennessy, Harrison and Wamakote (2010) identified a range of physical and educational factors that affect ICT integration and adoption in the classroom. These include, among others, unreliable access to electricity, limited technology infrastructure (especially internet access, bandwidth, hardware and software provision) and teacher attitudes towards ICT use. Among these factors, teacher-related variables such as teachers' attitudes towards ICT are found to be the most powerful predictors of technology integration (Sang, Valcke, van Braak, Tondeur and Zhu, 2011). Therefore, teachers' attitudes could positively impact ICT integration in the classroom at HEIs. The aim of this article is to indicate whether the attitudes of academic staff are an important factor influencing ICT use in the classrooms.

The study is limited to an investigation of the general use of computers and the use of computers to access the internet, even though ICT has a broader definition and includes a variety of technologies. Previous studies on ICT activity focused primarily on general use and importance of ICT in South Africa's education sector (e.g. Assar, El Amrani and Watson, 2010; Amedzo, 2007). To date, no published study has been conducted

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to assess the reaction of academic staff to ICT in South Africa. This study, therefore, is the first step in examining rural South African university academic staffs' attitudes toward ICT integration. The reason for selecting this particular university campus is that the university is well resourced with ICT facilities (Wario, 2014) and the researcher was keen to know whether the presence of a range of ICTs promotes ICT integration in the classroom.

A questionnaire survey method was adopted for this study to determine whether attitudes towards computer usage predict ICT integration in the classroom. The findings will then be discussed and conclusions will be drawn.

2. LITERATURE REVIEW

As a recent education innovation, ICT use in education is a complex process where many agents play a role. Forces at the micro-level of the educational system (academic staff and students) may be influential in facilitating or impeding changes that are outside the control of the institutions (Pelgrum, 2001). Unfortunately, much of the early research in computer use in education has ignored academic staff's attitudes toward the technology (Harper, 1987) and focused more on other aspects such as ICT importance in education, infrastructure and accessibility, thus overlooking the psychological and contextual factors involved in the process of educational computerization (e.g. Koo, 2008; Windschitl and Sahl, 2002). While the former aspects remain important considerations, it is usually the factors that are personal and deeply ingrained, such as academic staff's attitudes towards the computer and skills (Ertmer, 1999) that are considered to play a major role in the way academic staff generally integrates educational technology tools into instruction. Baylor and Ritchie (2002), in an examination of a number of American institutions, discovered that teacher-related issues were crucial in determining ICT use in the classroom.

Researchers have found that the success or failure of any initiatives to implement technology in an education programme depends upon academic staff attitudes towards the computer, which will influence its use in the classroom (Myers and Halpin, 2002; Isleem, 2003; Bullock, 2004; Huang and Liaw, 2005; Paraskeva, Bouta and Papagianna, 2008, Teo, 2008). Bullock (2004) found that academic staff's attitudes are a major enabling factor in the adoption of technology. Additionally, Yildirim (2000) found that teachers who used computers more frequently would tend to develop positive attitudes that promoted further use of the computer in their daily teaching tasks. However, one should notice that merely holding positive attitudes on the part of academic staffs can in no way ensure ICT use in the classroom as several studies reported cases in which low levels of computer integration were observed in academic staff despite their general positive computer attitudes towards computer (cf. Kim, 2002; Bolandifar, Noordin, Babashamsi and Shakib, 2013; Capan, 2012).

Williams et al. (2000) stated that the basic factors, which prevent ICT use in the teaching-learning process are lack of knowledge, skill and support. A later study conducted in 26 countries by Pelgrum (2001), confirmed that the basic barriers faced during ICT integration into the classroom were, amongst others, teachers' lack of skills and knowledge.

Ertmer (1999) divides the number of factors, which prevent ICT integration into classroom practice into two categories: the external (first-order) barrier, and internal (second-order) barrier groups. External barriers include those that are often perceived as key obstacles, for example, inadequate access to the technology, inadequate training and insufficient technical support. Internal barriers are ones that are academic staff-related such as attitudes, beliefs about teaching, knowledge, practices and resistance to computers. While many first-order barriers may be eliminated by securing additional resources for provision (once money is allocated), confronting second-order barriers such as academic staff's attitudes and skills remain a challenge and are often thought to cause more difficulties than first-order barriers (Dede, 1998; Fisher, David and Keith, 1996). Ertmer (1999) maintains that even when first-order (external) barriers are resolved, academic staff would not automatically use technology to achieve the kind of meaningful outcomes advocated, which will result in the under-use of this technology. In fact, bringing computers into the classroom does not necessarily influence the integration of ICT.

A similar sentiment was expressed by Wood et al. (2005) in which he stated that some of the first-order barriers might no longer be perceived as the insurmountable barriers that they once were. For example, the majority of academic staff members now have access to and use computers on a regular basis, making technical difficulties and lack of access less problematic. Therefore, academic staff–related variables such as attitudes and skills need to be considered for effective ICT integration into the classroom. This is important, because it is academic staff that has primary contact with students and it is academic staff that experiences the barriers and supports to integration of technology first-hand.

Computer related attitudes are influenced by a wide range of factors, which include computer anxiety (Yildirim 2000; Sam, Othman and Nordin, 2005), computer competence (Bingimlas, 2009), perception of computer attributes, cultural perception of computers and personal characteristics such as gender (Sadik 2006; Albirini, 2006), computer training (Tsitouridou and Vryzas 2003), teaching experience (Potosky and Bobko 2001; Kumar and Kumar 2003), age and educational level (Albirini, 2006; Tezci, 2011). Therefore, these factors are also investigated in this study.

2.1 Computer attributes

According to Rogers (1995), one of the major factors affecting people's attitudes toward a new technology is the attributes (characteristics) of the technology itself. Rogers identified five main characteristics of technology that affect its acceptance and subsequent adoption. The attributes, which determine an innovation's rate of adoption, are relative advantage, compatibility, complexity, trialability, and observability. Thus, a new technology will be increasingly diffused if potential adopters perceive that the innovation: (1) has an advantage over previous innovations; (2) is compatible with existing practices and values, (3) is not complex to understand and use, (4) can be experimented with on a limited basis before adoption, and (5) shows observable results. Rogers (1995:12) stated that "individuals' perceptions of these characteristics (attributes) predict the rate of adoption of innovations". Rogers further noted that although there is a lot of diffusion research on the characteristics of the adopter categories, there is a lack of

research on the effects of the perceived characteristics (attributes) of innovations on the rate of adoption.

This study will look at four of the five perceived attributes of innovation, namely; relative advantage, compatibility, complexity, and observability to test their influence on academic staff's attitudes towards ICT use in the classroom. Trialability was excluded because the majority of academic staff members may not have had an opportunity to experiment with computers before this study was introduced. Albirini (2006) found that the perception of computer attributes was significantly correlated to teachers' attitudes towards computers. Albirini's study accentuated the importance of computer attributes in the process of computer adoption in developing countries. Mwaura (2004) in her study, conducted in Ohio University found that relative advantage, compatibility and complexity were the most significant factors in predicting academic staff's intentions to make use of technology. Mwaura further suggested that the academic staff was motivated to use ICT in the classroom because of the perceived advantage that they gained from doing so. The advantages mentioned, ranged from their ability to post course materials online to easy communication with their students. In addition, the academic staff also perceived ICT to be compatible with their current teaching styles and easy to understand and use. Sooknanan et al. (2002) in their study, conducted in Trinidad and Tobago, reported that relative advantage, compatibility and observability were significantly related to the teachers' attitudes towards computers. However, their results did not show a relationship between complexity and academic staff's attitudes. Mwaura (2004) associated a sense of complexity with a lack of familiarity with technology and a lack of training. In contrast, Tornatzky and Klein (1982) reported that complexity had the most significant relationships with technology adoption.

2.2 Cultural perceptions

Rogers (1995) and Thomas (1987) emphasized the importance of the cultural/social norms of a given country in the acceptance of technology by its people. Norms are the established patterns of behaviour that tell members of the system what behaviour is expected (Rogers, 1995). According to Rogers (1995), social norms can be the main barrier to change. Martinez (1999) found that one of the major challenges facing developing countries was to make technology an essential part of the culture of the people. For example, it has been argued (Chen, Mashhadi, Ang and Harkrider, 1999; Collis, 1999; Joo, 1999) that ICT is racially white, Western, and male 'things' and that the internet itself overtly embodies American cultural qualities in terms of its language and technical users' values. Such kinds of cultural perception may prevent academic staff from integrating ICT into their classroom instructions. Collis (1999) argues that culture is a critical factor in influencing people's acceptance and use of ICT-based learning resources; therefore, understanding people's culture and how their culture influences behaviour, attitude and perception towards ICT integration in the classroom is important. A related study by Li and Kirkuk (2007) explored the effects of national culture on technology use among Chinese and British users. The researchers found that there were differences in technology experience, attitudes, usage and competence between the two nations, which were related to their national cultures.

Hyland (2003), in his study conducted at the University of Otago in Dunedin, New Zealand, found the academic staff dislikes using the internet to communicate with their students. To them, this form of communication was too impersonal which is be a finding directly attributable to their cultural perceptions. Modum (1998:29) notes that "cultural conservatism toward computers is responsible for the Nigerians' slow launch into the new information and communication age." Modum urges his people to "imbibe the values of the computer as a tool that can be used by all for problem solving, no matter their profession."

2.3 Computer anxiety

Several studies have demonstrated the effect of computer anxiety on computer-related behaviours (Bozionelos, 2001; Czaja et al., 2006; Kay, 2008; Agbatogun, 2010). Agbatogun (2010) in his study, conducted in Nigeria, found computer anxiety to be the strongest predictor of negative attitudes, which ultimately have a great impact on computer use in the classroom and the ability to learn to use computers. A high level of computer anxiety has been negatively related to learning computer skills (Harrington, McElroy and Morrow, 1990), resistance to the use of computers (Torkzadeh and Angula, 1992; Weil and Rosen, 1995), and poor task performance (Heinssen et al., 1987:53). However, with adequate training and provision of technical support, computer skills problems can be overcome and a favourable perception will be developed (Tekinarslan, 2008:1581). Meaningful training and professional development can increase academic staff's confidence and diminish these feelings of fear and/or anxiety.

2.4 Computer competence

In addition to computer attributes, cultural norms and computer anxiety, previous research suggests that the success of education innovations depends largely on the skills and knowledge of academic staff (Drent and Meelissen, 2008, Tezci, 2009; Son, Robb and Chatismiadji, 2012). Mooij and Smeets (2001) state that if academic staff members are not confident in their ability or competence to work with computers it may hamper their willingness to introduce technology in their classrooms. Berner (2003) in her study conducted among faculty members from five universities in Virginia, USA, also found that the faculty members' belief in their computer competence was the greatest predictor of their use of computers in the classroom. She argues that competence is an important factor fostering favourable attitudes towards computers.

3. RESEARCH METHODOLOGY

The target population in this study was all academic staff members currently teaching (both undergraduate and postgraduate) at QwaQwa campus of the University of the Free State (UFS) during the 2011-2013 academic years. This constituted a form of whole-frame sampling based on the principle of convenience of sample selection. Convenience sampling was used because it was more economical than any other approach because the researcher was based in the institution where the research was conducted hence, the participants were readily available. Tashakkori and Teddlie (2003) describe convenience sampling as a technique where elements of a sample are drawn from a group or sub-population which is readily available.

A questionnaire survey method was adopted for this study to determine whether attitudes towards computer usage predict ICT integration in the classroom. The questionnaire consisted of 105 items and included the following variables: biographical data, computer anxiety, attitude towards computer technology, computer attributes, cultural perception, computer competence and ICT integration.

The Computer Anxiety Rating Scale designed by Heinssen et al. (1987) was used to assess the subjects' level of computer anxiety. It is a nineteen-item scale where participants responded on a 6-point Likert-type scale with response options ranging from "strongly agree" to "strongly disagree". Attitude toward ICT Scale (Twenty attitude-related statements), computer Attributes Scale (eighteen items), cultural perceptions scale (sixteen items), computer competence (fifteen items) was compiled according to Albirini (2006). A 6-point Likert-type scale with response options ranging from "strongly agree" to "strongly disagree", except computer competence where options ranged from "no competence" to "extraordinary competence", was used.

Permission to conduct the study was obtained from the academic head at the campus. Ethical clearance was obtained from the Faculty of Education's Ethical Committee after the research proposal together with all the required documents explaining the nature of the research project, that is, the questionnaires and consent forms regarding participation, were prepared and submitted for approval.

A total of 100 questionnaires were distributed over a period of ten days. The questionnaires were delivered in person by the researcher to each academic staff member at their respective offices. This procedure was necessary to avoid low response rate. The academic staff members were given two weeks to complete the questionnaire. Three days before the deadline, the academic staff were reminded via email to complete the questionnaires. The questionnaires were collected in person by the researcher with a response rate of 84 per cent.

Descriptive and inferential analyses (full-model linear regression and Analysis of Covariance (ANCOVA)) were used to assess the relationship between attitudes towards computer usage and ICT integration in the classroom. These analyses were considered appropriate given the variables' nature and the hypotheses put forth. The data gathered from the respondents were coded by the department and then captured by the Department of Information and Technology Services at the UFS. These were then analysed using SAS. Univariate and full-model regression analysis were conducted using a 0.05 level of significance to test the relationship between the independent variables (computer anxiety, computer attitudes, computer attributes, cultural perception and computer competence) and the dependent variable (ICT integration).

4. RESUITS AND DISCUSSION

4.1 Descriptive analyses

Table1: Descriptive analyses of the respondents (independent variables)

Variable	n	Mean	Standard Deviation	Minimum	Maximum	Median	Mid-Point	Skewedness
Computer Anxiety	84	93.06	11.32	64.00	113.00	94.00	57	-0.37
Computer Attributes	83	88.06	11.16	60.00	103.00	90.00	54	-0.77
Computer Competence	82	60.41	14.67	0.00	84.00	62.00	42	-0.97
ICT Integration	82	45.02	8.67	21.00	60.00	45.50	30	-0.64
Attitude Towards ICT	84	100.75	16.31	39.00	120.00	105.50	60	-1.41
Cultural Perception	83	19.40	2.99	12.00	26.00	20.00	45	-0.34

Table 1 presents the independent variables of the participants. The medians in Table 1 indicated a high level of computer anxiety (94.00), computer attributes (90.00), computer competence (62.00) and level of ICT integration (45.50) when compared to the higher respective mid-points values (57, 54, 42 and 30). However, according to their respective values of skewedness (-0.37, -0.77, -0.97, -0.64) the distribution of these scores was normal (Brown, 2013:3).

The median value of computer attitudes (105.50) was higher than the mid-point of 60, which could have indicated that the sample had a positive computer attitude. According to the value of the skewedness (-1.41) the distribution was highly negatively skewed indicating that a large proportion of the respondents scored high on the scale (see Table 1).

Furthermore, the median value of cultural perception (20.00) was lower than the mid-point of 45, which could have indicated that the sample perceived the computers' cultural relevance as low. However, according to the value of the skewedness (-0.34), the distribution of this scores was normal (Table 1).

4.2 Inferential analyses (Full-model linear regression and ANCOVA)

4.2.1 Full-model linear regression

The relationship of ICT integration (dependent variable) and the independent variables (computer anxiety, computer attitude, computer attributes, cultural perception and computer competence) was analysed and the summary of full-model linear regression results is presented in Table 2.

Table 2: Results of full-model linear regression with ICT integration as dependent variable

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2681.550756	536.310151	11.94	<.0001
Error	75	3368.251713	44.910023		
Corrected Total	80	6049.802469			

R-Square	Coefficient Variable	Root MSE	ICT Integration Mean
0.443246	14.90857	6.701494	44.95062

Source	Degree of Freedom	Type III SS	Mean Square	F Value	Pr > F
Computer Anxiety	1	3.2910598	3.2910598	0.07	0.7874
Attitude towards ICT	1	3.8381743	3.8381743	0.09	0.7708
Computer Attribute	1	182.8799566	182.8799566	4.07	0.0472*
Cultural Perception	1	415.6933860	415.6933860	9.26	0.0032*
Computer Competence	1	993.6671230	993.6671230	22.13	<.0001*

Note: * variables that predict ICT integration in the classroom

According to Table 2, three variables affected ICT integration in the classroom at the 0.05 level of significance. These variables were *computer attributes*, *cultural perceptions* and *computer competence*. Computer anxiety and computer attitude were not significant predictors of ICT integration. These variables will be discussed below.

4.2.1.1 Computer attributes

The impact of computer attributes on ICT integration was significant ($p = 0.0472$). Computer attributes is the third most significant predictor of ICT integration in the classroom supports Rogers' theory on diffusion of innovation (1995), which contends that the attributes of the technology itself play a major role in determining its acceptability. An examination of individual computer attributes shows that respondents were more positive about the relative advantage (the benefit) of computers as an educational tool. The positive and significant contribution of relative advantage that was found in this study is consistent with previous research findings involving technology acceptance (Mwaura, 2004; Sooknanan et al., 2002). This finding is not surprising, because one would expect that the benefits of ICT will have a strong influence on the amount of usage.

4.2.1.2 Cultural perceptions

The impact of cultural perceptions on ICT integration was significant ($p = 0.0032$). Cultural perception, which is the second most significant predictor of ICT integration in the classroom, is synonymous with the supposition that social norms play a vital role in determining the rate of an innovation's adoption (Rogers, 1995). Thus cultural factors need to be considered in studies conducted in developing countries.

4.2.1.3 Computer competence

Computer competence was the most significant predictor of ICT integration in the classroom ($p < 0.0001$). The identification in this study of computer competence as the most significant predictor of ICT integration in the classroom supports the theoretical and empirical arguments made for the importance of computer competence in ICT integration (Pelgrum, 2001; Al-Oteawi, 2002; Berner, 2003; Albirini, 2006). Computer competence (skills and knowledge) enhances academic staff's ability to manage computer application. Therefore, the relationship between computer competence and ICT integration in the classroom suggests that higher levels of computer competence may increase ICT use in teaching and learning.

4.2.1.4 Computer anxiety

Computer anxiety did not significantly predict ICT integration in the classroom ($p = 0.7874$). This is a deviation from the findings of previous studies that indicated computer anxiety to be significant factors affecting ICT use in the classroom (Bozionelos, 2001; Czaja et al., 2006; Kay, 2008; Huang and Liaw, 2005; Uslu and Bümen, 2012; Van Reijswoud, 2009), but concurs with the findings of Tekinarslan (2008:1581), who postulates that more exposure to ICT will lead to less computer anxiety. The institution at which the study was conducted provides support (through the e-learning department) and exposing academic staff to the technology (availability of and accessibility to computers and ICT equipment) may have led to less computer anxiety.

4.2.1.5 Computer attitude

Computer attitude was not a significant predictor of ICT integration ($p = 0.7708$). This is in contrast to previous studies that indicate computer attitude to be a significant factor affecting the use of ICT in the classroom (Bozionelos, 2001; Czaja et al., 2006; Kay, 2008; Bullock, 2004; Albirini, 2006).

The difference in the findings regarding computer attitude may be attributed to the infrequent use of computers in classroom instruction. Yildirim (2000) stated that teachers who used computers more frequently would tend to develop positive attitudes that promote computer use in the classroom. Davis (1989) in his Technology Acceptance Model suggested that "perceived ease of use and perceived usefulness" were important innovation factors, determining academic staff's attitudes and subsequent acceptance of technology. However, one should notice that a high score on computer attitude on the part of academic staff alone cannot ensure ICT use in the classroom. Several studies have reported cases in which low levels of computer integration were observed among academic staff with considerably positive computer attitudes (Kim, 2002; Bolandifar et al., 2013:90). Kim (2002) ascribes this inconsistency to several constraints, including lack of time, insufficient knowledge and confidence deficiency. Therefore it may be said that even though academic staff have a high score on computer attitude, they may still not integrate ICT into their classroom instruction if they do not think that it will be useful or easy to use.

4.2.1.6 ICT integration

The R^2 value of 0.44 in Table 2 indicated that 44% of the variance in ICT integration was determined by computer anxiety, computer attitude, computer attributes, cultural perception and computer competence. This percentage was significant at $p < 0.0001$. So in part, all the independent variables predicted ICT integration. However, the step-wise model selection below will further delineate these relationships.

Table 3 and Table 4 demonstrates the stepwise-model selection where the variables, computer anxiety and computer attitude, were removed since the p-values of 0.7874 and 0.7708 obtained respectively were not less than the 0.05 level of significance.

Table 3: The stepwise-model selection where the variable, computer anxiety, was removed

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	2678.259697	669.564924	15.09	<.0001
Error	76	3371.542773	44.362405		
Corrected Total	80	6049.802469			

R-Square	Coefficient variable	Root MSE	ICT Integration Mean
0.442702	14.81740	6.660511	44.95062

Source	Degree of Freedom	Type III SS	Mean Square	F Value	Pr > F
Attitude towards ICT	1	6.986216	6.986216	0.16	0.6926
Computer Attribute	1	192.387846	192.387846	4.34	0.0407
Cultural Perception	1	421.222943	421.222943	9.50	0.0029
Computer Competence	1	1111.726449	1111.726449	25.06	<.0001

Table 4: The stepwise-model selection where the variable, computer attitudes, was removed

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2671.273480	890.424493	20.29	<.0001
Error	77	3378.528989	43.877000		
Corrected Total	80	6049.802469			

R-Square	Coefficient variable	Root MSE	ICT Integration Mean
0.441547	14.73611	6.623972	44.95062

Source	Degree of Freedom	Type III SS	Mean Square	F Value	Pr > F
Computer Attribute	1	347.686440	347.686440	7.92	0.0062
Cultural Perception	1	487.110690	487.110690	11.10	0.0013
Computer Competence	1	1110.265479	1110.265479	25.30	<.0001

According to Table 3 and Table 4, the independent variables computer attributes, cultural perception and computer competence still formed part of the final model and were significant prediction factors. Again, computer competence was the most significant predictor of the three ($p < 0.0001$). Thus, the R^2 value of 0.44 indicated that 44% of the variance in ICT integration can be explained by the three variables of computer attributes, cultural perception and computer competence.

4.2.2 ANCOVA of ICT integration in the classroom against confounding variables and independent variables

The confounding variables in this study are age, gender, ethnicity, academic rank, educational level, teaching experience computer training history and ICT use in the classroom. The confounding variables are included because of their anticipated effect on ICT integration. Table 5 presents their effect (both confounding and independent variables) on ICT integration.

Table 5: ANCOVA – ICT integration against all confounding and independent variables

Source	Degree of Freedom	Type III SS	Mean Square	F-Value	Pr > F
Age	1	20.6278113	20.6278113	0.84	0.3832
Gender	1	22.8186368	22.8186368	0.93	0.3601
Ethnicity	2	51.9058388	25.9529194	1.06	0.3868
Academic rank	5	132.3599865	26.4719973	1.08	0.4328
Educational level	3	132.4771630	44.1590543	1.80	0.2173
Teaching experience in years	1	30.1319862	30.1319862	1.23	0.2966
Time on computer training	1	6.0557268	6.0557268	0.25	0.6313
Years of ICT use in class	1	1.8235101	1.8235101	0.07	0.7913
Type of computer training over the last 5 years	1	4.7958805	4.7958805	0.20	0.6689
Computer Anxiety	1	8.9450655	8.9450655	0.36	0.5609
Attitude towards ICT	1	29.9221452	29.9221452	1.22	0.2982
Computer Attribute	1	0.4721446	0.4721446	0.02	0.8927
Cultural Perception	1	108.9364629	108.9364629	4.44	0.0644
Computer Competence	1	476.6306545	476.6306545	19.42	0.0017

According to Table 5, there was no significant relationship between ICT integration and age ($p = 0.3832$), gender ($p = 0.3601$), ethnicity ($p = 0.3868$), academic rank ($p = 0.4328$), educational level ($p = 0.2173$), teaching experience in years ($p = 0.2966$), time on computer training ($p = 0.6313$), years of ICT use in class ($p = 0.7913$), and type of computer training over the past five years ($p = 0.6689$). This suggested that academic staff had similar perceptions about ICT use in the classroom. These findings are consistent with that of Albirini (2006). Thus, personal characteristics are fast becoming an element not to consider when studying technology usage. This could be due to the fact that technology is now part of almost every aspect of modern life. Teo (2008) suggested that the more widespread use of computers by almost every member of the society has made the difference insignificant.

Regarding the relationship of independent variables (computer anxiety, computer attitude, computer attributes, cultural perception and computer competence) with the dependent variable (ICT integration) while controlling for the confounding variables, the result only showed computer competence to be a significant predictor of ICT integration in the classroom ($p = 0.0017$). However, in the full-model regression analysis, computer attributes, cultural perceptions and computer competences did predict ICT integration in the classroom. The differences in the analysis could be attributed to the interrelationship of variables. For example, in a full-model regression analysis, the effect of independent variables (computer anxiety, computer attitudes, computer attributes, cultural perception and computer competence) to dependent variable (ICT integration) were determined while in ANCOVA, the effect of independent variables and confounding variables (age, gender, ethnicity, educational level, teaching experience, and computer training history) to dependent variables were determined. Although none of the confounding variables was significantly related to ICT integration, their interactive effect diminished the significance of all independent variables including computer competence.Therefore this study chooses not to discard the effect of computer attributes and cultural perceptions on ICT integration.

5. CONCLUSION

Given the presence of technology in all sectors of education today, the study of academic staffs' personal factors becomes indispensable for planning and implementing technology integration. The challenge of technology integration into classroom instructions is more human than it is technological. The findings of this study may be specific to academic staff at one institution, but does not necessarily preclude academic staff from other institutions. Computer attitudes and computer anxiety were not predictors of ICT integration in the classroom, whereas computer attributes, and cultural perception were partial predictors. Computer competence was the most influential factor for ICT integration in the classroom.

Academic staff should be encouraged to use computers in their classroom instruction more often. The frequent use of computers in the classroom will lead to better computer skills, and consequently to ICT integration in the classroom. Given the growing presence of technology at universities, institutions should not only focus on providing computers for the academic staff, but also give them training and support in implementing ICT use in classroom instructions.

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Technology for Interactive Engagement or Tools for Differential Academic Participation? Using Google Groups for Collaborative Learning at a South African University

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ABSTRACT

The rhetoric on the potential of Web 2.0 technologies to democratise online engagement of students often overlooks the discomforting differential participation and asymmetrical engagement that accompanies student adoption of emerging technologies. This paper, therefore, constitutes a reality check of student adoption of technology as it explores the potential of Google Groups (i.e. student self-organised online groups) to leverage collaborative engagement and equal participation of students with minimal educator support. Community of Inquiry and a case study approach were deployed as theoretical and methodological lenses for unraveling the equality of participation, academic rigor of Google Group postings and the complexity interview transcripts of racially mixed students. Study findings were mixed: a semblance of authentic peer-based engagements, emergent academic networking, and breaches of interracial barriers was juxtaposed with gender asymmetries in participation, dominance of group administrators' postings and shallow collaborative engagements. The study, therefore, recommends an actively engaged educator who scaffolds student on-task behavior and a sound pedagogical strategy anchored in collaborative problem solving, authentic construction of knowledge and effective completion of collaborative tasks by students.

Categories and Subject Descriptors

H.5.3 [**Group and Organization Interfaces**]: Asynchronous interaction, Collaborative computing, Computer-supported cooperative work, Web-based interaction

General Terms

Human Factors.

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Keywords

Google groups, collaborative engagement, academic participation, collaborative learning

1. INTRODUCTION

A Group Group is a free, online discussion service from Google that allows users to chat individually and discuss in groups via Google Web pages or an e-mail system. Despite a growing body of research into collaborative learning using Google Groups (Harris, 2006; Abrantes & Gouveia, 2011; Marín & de Benito 2011), little is known about the capacity of autonomous, student-regulated Google Groups to enhance interactive engagement and equitable online participation among learners. For Ingram (2005), interactive engagement entails three aspects: 1. deep attention to the learning tasks and activities at hand; 2. activation of effective cognitive processes that improve both performance in the tasks and learning; 3. a social context for collaborative learning activities. Equitable online participation entails balanced participation through adequate access to the technology by students and the absence of undue dominance by any member or groups (Masters & Oberprieler, 2004).

While a Google Group is considered an academically productive forum for academic communication, organisation between workgroups and for discussion of topics proposed by the educator (Marín & de Benito, 2011), such engagement cannot be guaranteed if such groups were formed, managed and moderated by students with little or no involvement of the educator. In the absence of educator scaffolding (i.e. through allocation and organisation of discussion tasks around learning goals, assignment of roles to students and evaluation of the academic quality of discussions), student collaborative learning via Google Groups can be undermined by several factors. These challenges include non-participation of some students due to feelings of social exclusion (Zembylas & Vrasidas, 2007); student challenges with expressing themselves in the language of instruction (Chen, Bennett & Maton, 2008) and lack of sufficient academic knowledge of the subject under discussion.

This paper explores the impact of the adoption of Google Group by students (i.e. student-regulated groups) on their interactive engagement and academic participation. Interactive engagement is critical to deep learning because it facilitates the development of understanding of materials by students through sharing and evaluating their personal ideas and those of peers critically (Ho, 2002). Specifically, the study examines whether the use of a Google group enables equitable online participation among racially diverse students when limited support is rendered by the educator. Consistent with the foregoing discussion, the paper address the following research questions:

1. How effective are Google Groups (self-initiated and regulated by students) in the enhancement of interactive engagement?
2. To what extent is equitable participation among all Google Group participants achievable in the absence of educator regulation and support?

The paper is organised as follows: a literature review is articulated followed by a theoretical framework, the research methodology is then rendered, findings are presented, discussed and a conclusion is given.

2. LITERATURE REVIEW

2.1 Student interactive engagement

Interactive engagement describes the extent to which learners pay attention to the tasks, use effective cognitive skills (e.g. activating prior knowledge, elaboration, monitoring and comprehension) and interact with others in collaborative and cooperative learning contexts (Ingram, 2005). It prizes the learning and thought processes that unfold in group activities compared to the reflective processes that happen when someone is cogitating alone.

Studies on interactive engagement report on its potential to positively improve academic performance and enhance student retention (Finn, 1989; Summerlee, 2010), promote meaningful learning experiences and reduce dropout rates of students from under-presented and disadvantaged groups (Appleton, Christenson and Furlong, 2008; Parson and Taylor, 2011) and increase student regulation and control of their learning (Summerlee, 2010). In online learning environments, Beer, Clark and Jones (2010) propose that one possible indicator of interactive engagement is student participation, which is a potential indicator of behaviour activated by a students' motivation and quality of interaction. Online participation as an indicator of interactive engagement has been considered by several studies (Weaver & Albion, 2005; Sun et al, 2010). In a study that investigated the ability of social influence to increase user participation of online forums, Sun et al. (2010) employed sidebars that displayed forum threads to users as a strategy for heightening their presence and participation. Their study reports that buzzes in the sidebar of online users maximised participation by improving users' transparency through giving them the opportunity to view peers who re-shared, liked or commented on particular posts.

2.2 Academic participation

The Social Research Centre (2011) defines academic participation as a series of methods and processes that are specifically designed to actively involve students in influencing decisions that shape policies, practices, products or services (cited in Beamish, McDade, and Mulvenna, 2012). For Mulvenna (2012), academic participation provides students with the opportunity to articulate their minds, engage with peers' ideas, consider how their perspectives are conceived by peers and how they perceive the opinions of others. Participation in academic activities, therefore, does not only promote engagement with views of peers but also reflexive cogitation on one's thoughts as they relate to those of peers. Sfard (1998) conceives participation to involve dialogic interaction and co-construction of meaning that allows the co-construction of knowledge. This implies that participation in learning processes enables student access to learning content through dialogue and the development of new perspectives through engagement with peers' views. The assessment of student participation encourages their involvement in class discussions and active engagement with their own learning (Dallimore et al., 2006).

However, voluntary academic participation does not guarantee the involvement of all learners. Literature suggests that not all students are equally likely to participate in learning activities like a discussion, which can limit the value of discussion for students (Brookfield and Preskill 1999; Dallimore, Hertenstein, and Platt, 2010). Active participation of students in collaborative learning can be constrained by a number of factors such as their level of preparation, confidence in or fear of open discussion and the size of the class (Weaver and Qi, 2005). Prior exposure and familiarity with the topic under discussion or learning activity including student communicative competence have a bearing on the level and quality of participation of students. Student comfort in participation in collaborative discussions is dependent on prior experience of students in a given course, typical preparation, participation frequency, typical satisfaction with own participation and familiarity with and liking of collaborative discussions (Dallimore et al., 2006).

2.3 Participation in collaborative learning in Google Groups

Maslo, Surikova, and Gonzalez (2014) report that students created a Google Group to work collaboratively with the same document and to edit it as a team. Using this self-initiated Group, they participated in self organisation of interactive learning, solved the problems that arose collectively and used freely the academic staff as one resource among others. Harris (2006) assessed the potential of Google Groups to support collaborative online learning among 60 students enrolled for a distance course at a Caribbean Island university in Jamaica. They affirmed the capacity of Google Groups to foster multiple interactions between students (student-student; student-facilitator; student-course) through questions and answers posted online, facilitate e-learning of course materials and broaden communication among class members. Online technologies such as Google groups are

considered to trigger collaboration and document sharing among learners, heighten intensive interaction among students, faculty and content, enhance the active participation of learners, support peer-to-peer reflection on learning content and resources and enhance deep critical thinking (Yukselturk and Top, 2013). The opportunities for reflective engagement in Google groups derive from their asynchronous nature, which allows students to choose to post messages at their own convenience and do not require them to simultaneously log on to the software or platform in order to interact with one another (Hew and Cheung, 2012).

3. THEORETICAL FRAMEWORK

Since effective interactive engagement and equitable participation call into question student active engagement with the learning resources (i.e. strategies, learning materials, peer networks, educational technology), learning community and a collaborative learning context, a Community of Inquiry approach was a conceivably ideal 'lens' for unraveling and interpreting student engagement and participation levels.

3.1 Community of inquiry (CoI)

Garrison, Anderson & Archer (1999) developed Community of Inquiry (CoI) theory to explain how deep, reflective and interactive learning can be fostered practically within in a formal educational context. CoI provides a framework for describing the learning that takes place in online asynchronous communication by considering three core elements: *cognitive presence*, *social presence* and *teaching presence* (McDonald & Loch, 2008). Given that Google Groups constitute Web-based asynchronous communication mediated by group discussion threads, CoI provides a credible framework for exploring the meaningful student engagement and participation that unfold in these online learning environments.

3.1.1 Social presence

Social presence is the ability to project one's self and establish personal and purposeful relationships in an online learning environment (Garrison, 2007). It must transcend just establishing socio-emotional presence and personal relationships (Garrison, 2007) by ensuring that group members feel secure to communicate openly and coalesce around common purpose for a community to sustain itself (Thompson & MacDonald, 2005). As such, social presence should foster unity of purpose among Google group participants around collective learning objectives, foster meaningful relations and effective communication. It constitutes the social glue that allows students to identify themselves collectively as discursive community members whose common goal is to generate authentic knowledge and shared practices. A sense of collective identity is essentially critical to racially mixed online groups especially in South Africa, where the apartheid legacy and its discriminatory effects bequeathed some contours of racial identification and sustained prejudices that potentially undermine academic participation in higher education.

3.1.2 Cognitive presence

Cognitive presence is the exploration, construction, resolution and confirmation of understanding through collaboration and reflection in a CoI (Garrison, 2007). It fosters higher order thinking skills by emphasising practical inquiry and reflection. Critical thinking is the acquisition of deep and meaningful understanding as well as content-specific critical inquiry abilities, skills, and dispositions (outcome perspective) (Garrison, Anderson & Archer, 2004). Google Groups can bridge critical inquiry with experiential and lifelong learning by integrating personal knowledge and practice-based problem solving in real world contexts. Cognitive presence in Google Groups necessitates students to draw on peer-generated knowledge and self-concepts to position themselves inter-textually and discursively, to develop their own interpretations of issues, problems and situations.

3.1.3 Teaching presence

Teaching presence involves the design, facilitation and direction of cognitive and social processes for the realisation of personally meaningful and educationally worthwhile learning outcomes (Anderson, Rourke, Garrison & Archer, 2001). In Google Groups, teaching presence points at the pedagogical strategies necessary for inducting and scaffolding knowledge development and fostering academically mature learners. It foregrounds the appropriateness of tools-in-use and the effectiveness of pedagogical techniques deployed in student-peer and student-educator engagement. Where educator participation in Google Groups is restricted to online social presence without any substantive involvement in the provision and organisation of content (learning materials, questions, queries) and group activities (knowledge exchange, information seeking and information provision), teaching presence only manifests as an emerging phenomenon of limited relevance to students. To the contrary, when Google group administrators assume vertical roles of informing and advising peers, these roles constitute vital accoutrements of teaching presence.

4. METHODOLOGY

A case study approach was employed to examine the equity of participation on Google Groups of Masters in ICTs in Education at a South African university. A case study is ideal when the aim of the researcher is to unravel the meanings that subjects give to their life experiences and immerse herself in the activities of a small group of people in order to obtain an intimate familiarity with their social worlds (Fouch`e and Schurink, 2011). Since this study was concerned with understanding the impact of using Google Groups on student engagement and equitable participation, drawing on the social worlds and personal experiences of students drawing on their adoption of Google groups was considered ideal for this study.

Conference'10, Month 1–2, 2010, City, State, Country.

The objectives of the Masters in ICTs in Education programme were to: (1) Conceptualise educational challenges and formulate assumptions about educational technology, (2) Examine practical applications of learning theories and (3). Theorise the practical applications of educational technology and their relevance to developing countries (Centre for Educational Technology, 2008). In terms of overall structure, this two year programme was divided in two parts, coursework (Year 1) and mini dissertation (Year 2). The courses covered in first year included: the use of emerging ICTs in African countries, online learning theories and learning design, learning and teaching with emerging ICTs and research and evaluation of emerging ICTs. Upon satisfactory completion of first year coursework, students would proceed to Year 2 comprising a minor dissertation (see Czerniewicz, Ng'ambi and Hardman, 2008).

Eighteen students originally enrolled for the programme although only fifteen students completed course work. Since the majority of students were in-service teachers in tertiary education, primary education, government or corporate sector, the Module was run on a block release basis. The first semester of the Module was convened for approximately two months. The sessions, which involved mixed instructional approaches such as guest lectures, student seminars, group work, and individual project ran on Tuesdays from 1600-1900hrs. Five educators presented eight three hour sessions in the Centre for Educational Technology (CET), the venue where students and academics engaged intellectually with each other and with content. At the formative phases of the programme, the teaching team comprised the convener of the programme (an associate professor), three educators from CET (two associate professors, one lecturer) and one lecturer from the School of Education.

The ICTs in African developing countries course comprised lectures and seminars on a suite of emerging technologies used in the African educational systems such as blogs, wikis, podcasts, Google applications, social media (Facebook, Twitter), discussion forums, chat rooms and instant messaging applications. The majority of these services were already seamlessly integrated into the learning management system of this university. These theory-driven lectures and seminars were usually followed by practical seminars in computer labs where students were inducted and trained in good practices of using these technologies. Thereafter, students were expected to continually experiment with these technologies through social commentary on Facebook, blogging, wiki-based discussions and instant messaging.

4.1 Procedure

Two students (black female and white male) with more sophisticated knowledge of computers created a Google Group and invited peers to join, discuss their thesis topics, share their learning experiences and academic resources. Although the black female was an international doctoral candidate who had been requested by her study promoter to attend the Masters programme to familiarise herself with the uptake of educational technology in South African contexts, she was nevertheless, a highly experienced educational technologist with over five years of experience in online facilitation of learning at university level. The white male was a high school educator, learning designer and a technology champion who had spearheaded technology-assisted teaching at his high school. He had over seven years of experience in teaching with technology including online facilitation of student discussions on Moodle learning platform. With this diverse experience, therefore, these two students (or in service educators) were considered by the researcher as well placed to facilitate student engagement on Google Groups. They became Group site administrators who approved the signing of new group members, regulated their academic behavior and blocked access to non-class members.

Since it was a closed (i.e. restricted) group, only students who registered on it could access and read the discussion threads. Four students and the researcher joined the site and the default function on the Google group enabled all group members to receive e-mail notifications on every posting made. As the educator wanted students to retain ownership of the group and assume responsibility for discussions, he maintained an online presence but did not participate, unless when prompted to address challenging questions from students. Since the postings were based on creating a learning community rather than fulfilling course requirements, students were not obliged to make postings to the site. The postings were made for approximately 4 months.

4.2 Data collection *Data mining*

Since the researcher was a participant-observer on the Google Group, he had access to all the discussions on the site. After securing permission from the Group administrators and his peers, he downloaded all the publicly available student postings, printed them and analysed them quantitatively.

4.2.2 Interviews

The six Google Group participants were purposively selected to participate in scheduled in-depth semi-structured interviews. The interviews examined different contexts of using the Google Group, academic content exchanged by students, nature of learning resources accessed via this platform and their impact on student learning. The interviews were conducted in a laboratory foyer, a neutral, familiar and cozy space for most students. Interviews were audio recorded using a digital audio recorder, transcribed verbatim and analysed using thematic content analysis. Each interview lasted for approximately one hour.

4.3 Data analysis

4.3.1 Quantitative analysis

The purpose of quantitative analysis was to establish the equity of participation among the six group members. Therefore, it examined the number of postings per student, postings by the Group administrators, direction of postings, amount of peer feedback, and types of postings. To develop a visual representation of the information flows between participants and the extent of mutuality of transactions, a Social Network Matrix was developed. The matrix comprises numerical values that

represent different interactions between participants who share information and resources in a given context. The categories that emerged from an examination of quantitative analysis of postings are provided.

4.3.2 Qualitative analysis

In-depth semi-structured interviews were analysed using Burnard's (1991) thematic content analysis, which involves: (1) Identifying main themes from transcripts through immersion in the data, (2) Re-reading transcripts to identify loadings and categories and shedding irrelevant material, (3) Resorting categories and similar headings to form a relevant list, (4) Two colleagues (two educators) blindly validate research findings and three lists of categories are discussed and adjusted, (5) Transcripts and categories are [re]examined identifying data relating to each category and data is linked to category headings, (6) Transcripts are coded according to the developed categories and sub headings, (7) Respondents are asked to validate categories and adjustments are made as necessary and (8) Write up is conducted section by section with reference being made to transcripts.

Since the analysis was also informed by the Community of Inquiry (CoI) concepts (i.e. social presence, cognitive presence and teaching presence) and two main research questions focusing on interactive engagement and equitable participation themes, 7 categories were developed on interactive engagement and 4 categories were developed on equitable participation. On the interactive engagement theme, the main categories were: online social presence, embryonic knowledge sharing, critical questioning, creating learning communities, peer-based academic networking, instant communication and reflection. The equitable participation theme had the following categories: communication asymmetry, homophilous tendencies, peer-based clusters, and breaching racial boundaries.

Table 1:Using CoI concepts and research questions to analyse Google postings and interviews

Theme	Category	Evidence from Google posting/ interview data	Researcher comments
Social presence	Online presence	I have invited new people joining us this semester to join this group so that we can build our "community of practice" and I noticed some have already done so. They may not be reading their university mail yet, but next week we should see more joining us here online (Daniel, Google posting). I like Google chats because I know that my peer on the other side is waiting. As she types, I see a little icon written " Lorna is typing" so I know she is responding to me. Google chats provide different colours for users who are offline, busy, idle, or online so I know how to handle my peers (Interview).	Invitations and accepting invitations are critical components of recruiting online social presence and creating a vibrant online community. Anticipation of online peers and social presence on Google are antecedents to creating effective online networkers.
Cognitive presence	Embryonic knowledge sharing	Students can use Google groups to complain about the workloads given by academics, raise the concerns about unrealistic project deadlines, to request for additional reading literature during vacations when webmail is not accessible (Interview with Prudence).	Mutually shared concerns, on-task behaviours and sharing of pedagogical content knowledge sustain an academic learning community
	Critical questioning	According to a review of 21st century skills, Information Literacy suggests ..."the amount of electronic information doubles every hour" …need more than "twitch speed" to deal with this…however, my question is. Is there a 21st century learning style ? or is it more a smorgasbord of abilities that we need to be developing (Andy, Google posting)	Probing is a critical aspect of intelligent sharing of knowledge
Teaching presence	Instant communication	It's (Google chat) an online facility that is portable like a notebook so it means that I have no boundaries as to where and when my learning happens. When I have a question, I don't want to wait, I check Dr Murphy on Google for an instance response. I won't wait long for answers as I would forget my line of thinking (Interview with Shemiah).	Information seeking and instant educator feedback enhances the scaffolding of students by the educator.

5. PRESENTATION OF FINDINGS AND DISCUSSION

Quantitative findings are first presented followed by qualitative findings drawing on CoI concepts as interpretive lens. The quantitative findings first examine nature of postings, gender and racial representation of postings, communication asymmetry and homophilous tendencies of the engagements including differential engagement clusters. These findings address the question on equitable participation. The qualitative findings on the capacity of Google Groups to promote interactive engagement include its potential to heighten online social presence, promoted embryonic knowledge sharing and critical questioning, creating learning communities, peer-based academic networking, instant communication and reflection. These quantitative and qualitative findings are discussed in sections below.

5.1 Quantitative results on equitable participation

5.1.1 Nature of Postings

To unravel the equity of participation, it was critical to first examine the nature and level of participation by the six students. In spite of the fairly long duration of participation (4 months) and some semblance of collaborative learning, the overall participation was low (See Table 2). Eight postings were made that related to the sharing of course information, academic URLs and videos on course activities. Students also exchanged project related information and academic research interests. On rare occasions, students exchanged IT news and interpretations of personal experiences of the course. Overall, student uptake of discussions on theoretical concepts was austerely limited (see Table 2). This shallow learning signifies the difficulty of accomplishing complex learning tasks in the absence of educators who provide structure

and sequence to learning tasks, monitor student on-task behavior and reduce the cognitive load on them. As Brack & Van Damme (2010) aptly suggests, students need support in the effective adoption of technology to engage in constructive collaborative dialogue rather than mere messaging; to refine group processes, clarify problems and checking ideas.

Table 2: Nature of posts and their frequencies

Nature of Google Group postings	Frequency
ICT news	2
Compliments	5
Academic information, videos and URLs	8
Logistics	2
Academic project information	2
Research	2
Exhortations	1
Observations and interpretations	2
General announcements	4
Critique	1
Notification	1
Total posts	30

5.1.2 Direction, gender and racial representation of postings

Unraveling the equity of participation necessitated disaggregation of postings by race and gender, nature and direction of these postings. Although all participants posted messages on the Google Group, the two administrators (black female, white male) dominated the Group. In fact, despite the skewed gender distribution of postings and unequal gender representation (5 males: 1 female), the female administrator was one of the dominant members of the group with regard to postings. While her status as a Group administrator and a PhD candidate in Educational Technology partly explained her technological confidence and profound knowledge, her dominance seemed to counter the popular view that intra-group dynamics often undermine the assertiveness of female participants in male dominated groups. The dominance of the group by few individuals and non-participation of peers can be interpreted possibly as a consequence of feeling of exclusion [by academically weaker students] and their silencing [by academically dominant members] (Zembylas & Vrasidas, 2007) as online interactions are not insulated from the exercise of academic power. Academic knowledge derived from academic level, confidence in use of new technology and linguistic competence all influence student ability to actively participate in online learning environments. Therefore, the need to fit in the group's learning pace or level of discussion might sometimes adversely affect personal aspirations and achievements (Zembylas & Vrasidas, 2007). Yet the fact that the female participant constituted a minority in the group did not deter her from dominating the group albeit some gender imbalances. That said, males collectively posted more posts than her.

Although the Google Group had balanced racial representation (3 blacks, 3 whites), whites posted slightly (4 posts) more posts than blacks. Overall, the majority of posts were directed at all group members and not specific individuals suggesting evidence of collaborative sharing of information and balanced interaction. Google applications such as groups, chats and documents are highly valued for their collaborative and developmental potential. For instance, Google Docs [just like Google Groups] are credited with increasing student responsibility for collaborative learning, heightening student feeling of psychological ownership (Blau & Caspi, 2009). The assumption of group administrator roles and moderation of group discussions is one such expression of psychological ownership by group members.

Notwithstanding the modest racial imbalances in participation, there were strong interracial interactions on both academic and social issues suggesting the value of shared norms in promoting sustained engagement. For instance, Rimor, Rosen and Naser (2010) observe that for group participants to succeed in online group work, they should invest in developing shared norms and work procedures.

5.2 Social Network Matrix (SNM)

To examine the extent of representivity of the postings and equity of participation, mined data was used to develop a SNM that displays the direction and intensity of inter-personal communication.

Table 3: Social Network Analysis Matrix

	Daniel	Prudence	Amanda	Andy	Geoffrey	Shemiah
Daniel	0	**9**	**10**	**9**	**9**	**9**
Prudence	3	0	2	1	1	1
Amanda	**5**	**6**	0	**7**	**5**	**5**
Andy	4	3	4	0	5	3
Geoffrey	0	0	0	1	0	0
Shemiah	1	1	1	1	1	1

As the matrix shows (see Table 3), Amanda and Daniel (pseudonyms), the group administrators dominated the interactions judging from the number of posts made to the group. The general apathy of the other four participants demonstrates the complexity of maintaining equitable participation in the absence of academic regulation and incentives.

5.2.1 Communication Asymmetry due to moderator domination

To examine the equity of participation the volume and direction of interactions were examined. The group administrators were the nerve centres of information-judging from their central location and number of postings they posted. Collaborative engagement, therefore, was asymmetrical as there was significant outward communication from Group administrators to peers but limited feedback from peers to administrators. Therefore, peer dominance is conceived as inimical to group collaboration and original independent thought (Rimor, Rosen & Naser, 2010). We infer that the group administrators' familiarity with Google groups, relatively sophisticated computer proficiency coupled with their hyper communicative qualities worked to sustain unbalanced discursive participation between participants.

Given that all postings were visible to group members through Google Group notifications and were persistently available, the paucity of discussions on academic content was disappointing. We infer that effective use of the technology depends on student motivation to engage in on-task behavior, academic efficacy of the Google Group as perceived by members and enthusiasm of group members to contribute to public, collective spaces to ensure equitable participation. This finding potentially consummates previous research which suggests that students with high digital competence and a positive attitude towards digital tools have more positive perceptions about technology-mediated learning (Brodahl, Hadjerrouit & Hansen, 2011) thus contributing to heightened participation of such students.

5.2.2 Homophilous tendencies

Although not necessarily a dominant feature of Google interactions, homophilous tendencies of group members of directing their queries to friends were conceivably inconsistent with Group administrators' behavior of posting queries to the entire group. Such homophilous tendencies promoted skewed interactions among group members. For example, a group member (black female) who was acquainted with her peer's (black male) research project on the academic appropriation of social media sent an informative article to him:

> I know you are working on Facebook research. Follow this BBC link below and see if the article makes sense (weblink provided)(Amanda).

As such, while meaningful collaborative engagement necessitated the mutual co-existence of inter-personal communication with group engagements, conversational dyads potentially activated skewed communication by ignoring the collective needs of the entire group. Since group interactions were aimed at heightening knowledge seeking and information exchange among all group members, striking a balance between individual needs and group learning expectations was necessary for meaningful learning.

Peer-based interactions threatened to split the cohesive group into two engagement clusters. One student highlighted these fissures:

> We seem to have two separate Google Groups for the course. Is this a concern? Having several groups gives more of us a chance to experience owning and managing groups. We get to see the [engagement] problems firsthand and [this] gives us the confidence to use Web 2.0 sites in our own teaching once. We see that it is not a frightening experience. Are there people who are not members of either groups? Are there other groups for this course? Should we try to unify the groups? (Daniel posting).

For these students, the different groups conceivably afforded them the opportunity to assume responsibility and ownership of knowledge production. While using technology to experiment with new roles potentially broadened their familiarity with affordances of technology, it was not clear how these different groups were exploited to equalize participation of all Group members. Although personal cliques were not a profound feature of group collaboration, when sustained over time, they potentially created fissures in participation and asymmetrical communication among learners thus denying peers opportunities to engage with the entire group.

5.2.1 Breaching racial boundaries

One possible expression of participation was evidenced by the power of the Google Group to democratise peer-based engagements and bridge racial barriers among students. It was a user-friendly way of grasping acquaintances' learning needs, research interests, and overcoming racial stereotypes and anxieties of engaging with peers from unfamiliar cultural backgrounds. A black student articulated the value of the Google Group as follows:

> It enabled me to chat with white guys about our profession and school work more freely. It allows us to get rid of the communication 'holes' between different races. Anxieties and fears of talking to unfamiliar racial groups are removed because on Google group they just have to respond (Interview with Shemiah).

Inter-racial communication on Google Groups gave more students the confidence to share knowledge and articulate their views without the anxiety or fear of public ridicule or potential contempt from peers from other racial groups. This nascent participation demonstrates the extent of student involvement in scholarly discourses as it "indicates if learners had theoretically [...] be[en] able to acquire knowledge within the environment" (Weinberger & Fischer, 2006, p. 73).

In relation to the equalisation of communication, a coloured student (who constructed her identity as black) affirmed that:

> Google Groups break social boundaries. I remember, after conversing with Joy (Black female classmate) on Google, we met in class and I asked her to hug me, so I got to know her more personally thereafter (Interview with Kirsty).

Inter-racial communication empowered students to challenge entrenched racial stereotypes and barriers bequeathed by apartheid legacy in South Africa. If these social interactions were exploited for academic engagement, they would have fostered rich academic ties vital for authentic knowledge production.

6. QUALITATIVE FINDINGS ON INTERACTIVE ENGAGEMENT

These findings were discussed under the broader ambit of CoI concepts namely social presence, cognitive presence and teaching presence. Under these main conceptual themes, various categories were discussed as shown in sections below.

6.1 Social presence

6.1.1 Online presence

Social presence involves individual social awareness of other interactants who are online at any given time, in both spatial and temporal dimensions. Because Google Groups enable users to spot the online status and presence of peers, they provide users with clues on possible future permutations on interactive engagement with peer group members. Invitations through Google notifications via personal emails, joining of the group and confirmation of membership were critical precursors of online presence:

> I have invited new people this semester to join this group so that we can build our "community of practice" and I noticed some have already done so. They may not be reading their university mail yet, but next week we should see more joining us here online (Daniel).

The statements demonstrate the mediation of technology in locating and recruiting prospective online participants for academic engagement. Google Group interactions also potentially heightened student interactive engagement by alerting them to the status (i.e. ready to chat, busy, idle and offline) of their online peers and thus informing them of appropriate moments to initiate, terminate and re-engage in conversations. High social presence facilitates group dynamics that support the development of a sense of personal belonging and community among group members (Picciano, 2002; Hovey; 2014). Social presence awareness was cogently epitomised by one student in her choice of Google chats:

> I like Google chats because I know that my peer on the other side is waiting. As she types, I see a little icon written "Lorna is typing" so I know she is responding to me. Google chats provide different colours for users who are offline, busy, idle, or online so I know how to handle my peers (Interview with Amanda).

Recruiting attention and anticipation of peers is an essential component of social presence awareness critical to interactive engagement on Google Groups. Social presence is impacted by the availability of personae, their intentions and meaning making, which affect the existence and nature of interaction between two or more peers (Cui et al., 2012; Hovey; 2014). Therefore, social presence awareness not only connected interlocutors psychologically but also afforded emotional presence as well.

6.1 Cognitive presence

6.1.1 Embryonic knowledge sharing

Students also leveraged their engagement activities through information seeking and sharing of academic materials (i.e. work in progress, project assignments, URLs, books and readings). When one student posted an interesting article on Facebook, a protracted discussion with peers on Google Groups ensued:

> The article is showing how Facebook can generate public awareness about a particular topic in a short space of time. A wine farm near us uses it as a marketing tool. They started a "I love xxx wines" group and get students to join. They make it cool to belong and they get invitations to events where XXX wines is the sponsor. Could we do the same with a Maths class? (Daniel).

The practical application of technologies unfolded as the student related the article to real world contexts, and then posed a question in his field of Mathematics Education. The authentic application of technology in contexts suggests that students transcended social presence awareness by using Google group for contextualization of theoretical knowledge on Connectivism. In learning tasks, students need to develop learning strategies beyond the surface level by applying their collaborative learning strategies, monitoring their learning activity and maintain coordination between multiple strategies (Abdelraheem & Asan, 2006).

The student's peers had different notions of how the technology could gainfully support the administration of courses. As one student observed:

> Google Groups and chats could be used for students' voicing of the amount of work load given by academics, their concerns for project deadlines, quest for additional reading literature during vacation when webmail is not accessible. For any subject, anyone of these could be useful (Interview with Jeoffrey).

6.1.2 Critical questioning

For this technology course, alerting peers to innovative uses of Web 2.0 technology proved useful. Students exchanged content related to information technology that was critical to heightening interactive engagement. For example, one student employed the information from an online article to formulate a question about 21st Century learning styles:

> According to a review of 21st century skills, Information Literacy is challenging as..."the amount of electronic information doubles every hour" …need more than "twitch speed" to deal with this…however, my question is. Is there a 21st century learning style? or is it more a smorgasbord of abilities that we need to be developing. My take on this is one size does not fit all...smart living? See http://www. 21stcenturyskills.org (Andy).

Reference to 21st Century skills, information literacy and electronic information all point to student exchange of information relevant to the discipline of ICTs in Education, the discipline they were enrolled in. Such probing suggests the potential of Google groups to foster critical questioning necessary for deep learning. Promoting deep learning, inter-personal and intercultural collaboration is critical because the focus of Web 2.0 technology is not necessarily the technology but rather its appropriation to foster higher order thinking by using it on tasks that require

problem solving, reflection, and cooperation (Fogarty & McTighe, 1993).

In response to this question, useful knowledge sharing unfolded as peers gave invaluable information that assisted them connect prior knowledge to new knowledge, thus sustaining interactive engagement. A peer furnished the aforementioned student with a web address that hosted useful resources:

> Interesting question! I was looking through some references and found something that you might find relevant. See web address below (URL provided). It is a site of a book review. Look at chapter 2 (p. 16 onwards) (Geoffrey).

Therefore, student in-class interactions were complemented by the exchange of pedagogical content knowledge on the Google Group, which contributed to student development of their critical thinking skills and increased their stock of knowledge. As such, the Group served as a catalyst for the generation of collective intelligence.

6.2 Teaching Presence

6.2.1 Instant communication

Students foregrounded instantaneous communication between students and academics. Although the educator maintained a muted social presence on the Google Group, students claimed that Google Groups potentially enabled just-in-time learning by allowing them to connect with academics as per and when they needed their assistance:

> It's [Google chat] an online facility that is portable like a notebook so it means that I have no boundaries as to where and when my learning happens. When I have a question, I don't want to wait, I check Dr Murphy on Google for an instance response. I won't wait long for answers as I would forget my line of thinking (Shemiah).

Since there was no evidence of elaborate educator-student interaction on Google Group, it can be inferred that this student interacted with educators via Google chats (private chats) and not the Group (public for participants). Given that students learned across different contexts, educator provision of instant feedback was a productive affordance of Google chats. Generation Y students are impatient about inordinate delays in securing feedback as they are considered to construct deferments as hindrances to mobile and lifelong learning.

6.2.2 Deep reflection

Collaborative learning processes in Google Groups were positively associated with higher reflection among students. Deep reflection was conceivably interlaced with opportunities to pose investigative questions to educators, thus potentially negotiating disciplinary power with them. Student reflection bridged their social distance with academics as it bolstered their confidence to approach academics with tough questions whenever they were online:

> Google talk gives me the opportunity to probe my educators and peers to get responses from them and to reflect deeply over issues because I can review the Google chats as these responses are persistently documented online (Interview with Andy).

Digital trails of past interactions bestowed students with footprints of the transactional exchanges and the muddy processes of knowledge production. Unlike lectures, which are often punctuated by monolithic, unidirectional delivery, Google chats rendered students with talk-back processes during their interactive engagements.

6.3 Study implications

Study findings highlighted online administrators' domination and the gender asymmetry of postings as shortcomings of student interactive engagement in the absence of educator regulation. A multi-pronged pedagogical strategy involving rotation of student leadership (i.e. group administration rights), requiring differentiation of individual roles (information seekers, information givers, information synthesisers, critics, providers of question prompts) for any given learning task and disintegration of group into smaller clusters would enhance individual student participation.

To prevent general non-participation by some students, educators should adopt a more proactive presence at different phases of executing learning tasks, assign different roles to students, encourage group participation by integrating participation with assessment and provision of prompt feedback to struggling students when group members fail to resolve complex learning tasks (problems, questions).

A holistic pedagogical strategy that integrates intentional learning, collaborative problem solving, deep personal reflection, and interracial communication is necessary to address the challenges of surface approaches to learning, limited inter-personal engagements with peers and the educator. The pedagogical design and execution of learning tasks should foreground cross-cultural collaboration through providing requirements for the accomplishment of tasks by racial mixed groups, giving learning tasks that require the articulation of epistemological and propositional knowledge, tasks that require individual reflection, cluster cooperation and whole group interaction

7. CONCLUSION

The current study investigated the impacts of the academic appropriation of Google Groups on effective interactive engagement. The academic use of Google Groups was an oxymoron that heightened emergent academic networking, student access to knowledgeable peers and academics, and improved the online visibility of interactants thus setting the intellectual stage for fruitful conversations. However, collaborative interactions were suboptimal because of limited academic rigor on content, insufficient student reflexivity and criticality and scant evidence of cognitively demanding academic activities.

The research also explored whether equitable participation was plausible in Google Groups when academics took a backseat role in online interactions. The evidence was also mixed: the Google Group enabled inter-racial communication that bridged peers'

social distance, breached inherent racial barriers and stereotypes by enticing all group members to make contributions. Equitable participation also manifested in group postings that created a sense of collegiality and group cohesion around interactants' shared interests, resources and mutual research interests. Nevertheless, the downsides of Google Groups were site administrators' dominance of group members, salient gender disparities in the postings and "girl power" that unfolded through the hegemony of the only female student in the group. The study concludes with a strong pedagogical strategy rooted in active educator presence, the coupling of pedagogical goals with student participation, and modeling activities so that the academic issues become a central part of task design, their sequencing, implementation, and assessments, is necessary.

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An Experiment in Using Gamification in an Information Technology Distance Classroom

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ABSTRACT

Gamification is defined as the use of game mechanics in a non-gaming environment in order to solve problems and engage users. Students in distance learning environment are often un-engaged or not fully engaged in their class work. This paper describes an experiment in incorporating game mechanics in a distance learning class mediated over the Internet. The author taught a one semester course in 2013 which did not incorporate game mechanics. In that course, nearly 80% of all homework was returned late by the students. In 2014, the author incorporated eight game mechanics into the course keeping the remaining content of the course the same. These eight game mechanics were over-arching story, short term missions, points, leaderboards, badges, leveling, onboarding, and engagement loops. In the 2014 semester, nearly 60% of the homework was returned early before the deadline. Students even wished to continue to submit homework after the final examination in order to receive additional badges. The results clearly show that gamification increases student engagement in courses.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education

Keywords

Gamification, Android, mobile

1. INTRODUCTION

Gamification is the use or incorporation of game mechanics into a non-gaming environment with the purpose of solving problems and engaging users [10, 11]. Gamification is not to be confused with game-based learning. Game-based learning focuses on putting educational content into games [12]. Gamification focuses on putting game mechanics into education.

Students taking part in distance education are often not as engaged in their coursework as students taking part in contact (face-to-face) education. In a 2013 report by the South African Council of Higher Education, the estimated percentage of students who drop out and do not complete their 3- and 4-year degrees at contact universities is 45% while the same measurement at UNISA (a South African distance university) is 78% [22]. In a 2012 interview, Daphne Koller, co-founder of Coursera, reports a 7% to 9% retention rate in MOOCs [15] which corresponds to a 91% to 93% drop out rate. In a 2012 Duke University MOOC, 12,725 students registered for the course and only 313 earned a completion certificate – creating a 2.45% retention rate or a 97.55% drop out rate [5].

In 2013, the author was invited to teach an Internet mediated Information Technology course for Sudan University of Science and Technology. The author was based in South Africa and the students were based in Sudan and in Saudi Arabia. The course was configured as a "flipped" classroom with videos and reading materials being sent to the students one week before the class met. The class then met using video conferencing after which homework would need to be done in the subsequent week [4]. During the 2013 course, over 80% of the homework was returned late with much of the homework only being returned after the last video conference meeting but before the final examination.

In 2014, the author was invited to again teach the same Information Technology course. In an effort to pre-empt the problem of late homework returns, gamification was investigated as a possible solution. Eight different game mechanics were added to the course keeping the content of the course constant.

The course itself was a one semester overview course which covered Information Technology tools and utilities which could be used to assist mobile education specific in constrained environments. Topics included the use of wikis, blogs, chat rooms, email, e-books, etc.

In view of the fact that this experiment could be considered to be experiments with human subjects, an ethics application was made to the research ethics committee of Sudan University of Science and Technology. After reviewing the application, the committee felt that the research was aligned with its rules and regulations and an ethics clearance certificate was issued. In addition, all students were over the age of 18 and free to withdraw from the gamification aspect of the course if they wished.

SACLA 2015, 02-03 July, Johannesburg, South Africa

This paper will first provide some background about games and gamification. The paper will then describe the eight game mechanics which were added to the course. Results will then be provided followed by concluding remarks.

2. BACKGROUND

People have been playing games for thousands of years [2]. The ancient Egyptians [9], Romans[20] and Greeks [2] all played games. The board game mankala (or mancala) which is widely played through-out Africa is estimated to be between one thousand and three thousand years old [24]. The games of Go [2] and Chess [7] are also estimated to be thousands of years old.

One of the first researchers to investigate the place games have in society (and not the games themselves) was Dutch historian Johan Huizinga. Huizinga wrote originally in German which was later translated into English. He published *Homo Ludens: A Study in the Play Element in Culture* contrasting the term *Homo Ludens* (Man the player in the original German) with *Homo Sapiens* (Man the Thinker) [14]. Huizinga argues that play has five essential elements 1) Play is voluntary 2) Play is not ordinary life 3) Play is distinct from ordinary life both in location and time 4) Play requires a certain order 5) Play has no material benefit or profit [14]. Huizinga provides this definition of play:

> "...[play] is a free activity standing quite consciously outside 'ordinary' life as being 'not serious', but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner. It promotes the formation of social groupings which tend to surround themselves with secrecy and to stress their difference from the common world by disguise or other means."

For anybody who has observed people playing modern computer games, Huizinga's comment that games "[absorb] the player intensely and utterly" is extremely accurate.

Computer game designers use the term *meaningful play*. Meaningful play describes the situation where "...the relationships between actions and outcomes in games are both discernible and integrated into the larger context of the game" [21]. This aligns with Huizinga's belief that games "require a certain order." It might be possible to modify the definition of *meaningful play* to *meaningful learning* to describe the situation where "...the relationships between actions and outcomes in education are both discernible and integrated into the larger context of education."

Gamers often describe a state of total engagement into the game where their skills are sufficiently challenged to achieve the goals of the game. This intense concentration is called *flow* by psychologist Mihaly Csikszentmihalyi [6]. According to Csikszentmihalyi, a number of conditions must be met in order to achieve flow. The individual must have a chance of completing the task. The individual must be able to concentrate on the task. The task must have clear goals. The individual must have a sense of control over his or her actions. The individual must receive immediate feedback.

In her book *Reality is Broken – Why Games Make Us Better and How They Can Change the World*, Jane McGonigal [17] describes how gamers are abandoning reality for a virtual world where their skills are challenged, where they can collaborate with others, where they are rewarded for achievement, and where they can save the world. She asks

> "Where, in the real world, is that gamer sense of being fully alive, focused, and engaged in every moment? Where is the gamer feeling of power, heroic purpose, and community? Where are the bursts of exhilarating and creative game accomplishment? Where is the heart-expanding thrill of success and team victory?"

Gamification attempts to extract key mechanics from games which embody meaningful play and encourage *flow* and attempts to insert these mechanics into the educational environment in order to create meaningful learning. Gamification in education can be viewed as a strategy of using game elements in educational situations in order to support teaching and learning goals [3].

3. GAMIFICATION IN SOUTH AFRICA

There have been a number of examples of gamification in education in South Africa. These examples have been both academically published and unpublished. This section will describe three such projects: the ICT4RED teacher professional development program, a game development module at University of Cape Town (UCT), and similar module at University of Pretoria (UP).

3.1 ICT4RED

The ICT4RED (ICT for Rural Educational Development) project was part of a research program initiated by the South African Department of Science and Technology in collaboration with the South African Department of Basic Education, the Eastern Cape Department of Education and the South African Department of Rural Development and Land Reform [3]. Within ICT4RED, the Teacher Professional Development project aimed to guide the development of relevant teacher knowledge and proficiency to enable classroom practice to portray a 21st century teaching and learning engagement.

Gamification was purposefully chosen for the Teacher Professional Development project. Game mechanics such as rapid feedback, progression, story telling, and badges were incorporated in the project. Going beyond merely virtual rewards such as badges, the funding provided for the project allowed the participants on the Teacher Professional Development project to

"earn" the ownership of the technology used (a tablet) on the module.

3.2 University of Cape Town

At the University of Cape Town, a Computer Science module in 2D game designed was gamified [19]. The gamified module had a steampunk theme and the participants were introduced to the "Order of the Curmudgeons" which was an order of mad scientists. The major story line was the mystery of a missing "Crowther Engine" (similar to a Babbage engine). During the course of the module and the gamification exercise, participants earned clues to solve the mystery by completing tasks. Participants earned points by attending lecture and taking part in activities. The gamification exercise included different types of points, leaderboards, badges, and progress bars all visualised with steampunky artwork.

This UCT study showed improved student performance and better lecture attendance.

3.3 University of Pretoria

At the University of Pretoria, games study lecturer Koos de Beer also added various game mechanics which had real-world value within his class environment. Comparing this with the ICT4RED project, ICT4RED had external funding to provide real-world awards (such as tablet technology) whereas de Beer's project offered virtual awards which had real-world value within the context of his class environment. At the time of writing this paper, de Beer's research in gamification is as yet unpublished and this information was gleaned from interviews with students on de Beer's course and with direct email with de Beer. Additional information about de Beer's research can be found on his blog [8].

In de Beer's gamification exercise, students earned points or vouchers which had real-world value within the class environment. The points or vouchers were earned by achieving certain goals created by de Beer in a persistent multiplayer world of Minecraft which was hosted on a server at the University of Pretoria. For example, if a student completed a specific player created goal in Minecraft, he or she could be awarded with a voucher which gave him or her a time extension on a subsequent assignment. Another voucher which could be earned entitled the student to a certain percentage increase on individual or group assignments (not necessarily examination results). According to the students interviewed, these vouchers and awards encouraged the students to do exceptionally well on their assignments and projects.

The awards also gave the players motivation to participate in the provided opportunity to play Minecraft with their fellow students. This in turn gave the players a shared experience in a multiplayer game (certain students have never played multiplayer games before). The shared experience enabled de Beer to use Minecraft examples in class when explaining game design theory. The results were better understanding of certain concepts from the students.

3.3 Differentiation of this Research

The three gamification exercises described in this section all involved the use of game mechanics in a face-to-face classroom environment. The research described in this paper, however, differs from these three previously described research projects. This research is specific to the use of game mechanics in a distance classroom where the lack of student engagement is a known problem.

4. RESEARCH METHODOLOGY

Design Science Research promotes the creation of innovative artifacts in order to solve important problems [25]. There are five possible artifacts of Design Science Research: constructs, methods, models, instantiations, and better design theories [13]. Constructs provide the vocabulary of the underlying domain. Methods are algorithms or steps. Models define inter-relationships between constructs and methods. Instantiations are implementations of methods and/or models in the real world. Better design theories can be created when the created artifact exposes new relationships between its elements which were previously unknown.

This research created two Design Science Research artifacts: a model and an instantiation of that model. The model created was entitled the Journey model. The Journey model describes a model which sends students on a journey of discovery. Along the journey, students are sent on missions, earn points and badges, etc. The model was instantiated as an Expedition to Phobos and Deimos where students were assigned to the Information Technology department on a luxury passenger spaceship traveling to two of the moons around Mars – Phobos and Deimos.

The instantiation artifact was embodied as an Android application which students could download onto their personal smart devices. In support of the mobile application, a Java Enterprise application running on a Linux server provided the glue which linked the students and author's Android applications together.

5. EIGHT GAME MECHANICS

The Journey model uses eight common game mechanics. All of these eight mechanics were implemented in the Expedition to Phobos and Deimos instantiation. These eight mechanics are: over-arching story (or long term goals), short term missions, points, leaderboards, badges, leveling, onboarding experience, and engagement loops. Each of these mechanics will be described giving examples of how these mechanics were used in other projects and how they were implemented in the Expedition to Phobos and Deimos.

5.1 Over-Arching Story

The over-arching story gives a gamification exercise meaning. Using Huizinga's definition, the over-arching story makes the gamification exercise stand "...quite consciously outside 'ordinary' life." An example of gamification in health applications is the mobile application Zombies Run [1]. The Zombies Run mobile

application provides an over-arching story to better engage people who want to improve their health by running and jogging. The application virtually places the person in an post-apocalyptic world where the zombies are taking over. With vibrant background music and creative sound effects, the person must outrun the zombie hordes.

The over-arching story in this instantiation of the Journey model is an Expedition to Phobos and Deimos. The student is assigned to the Information Technology department of a luxury passenger spacecraft traveling to two of the moons around Mars – Phobos and Deimos. Artwork was created which was included in the Android application and also used to brand the written documents used during the course.

5.2 Short Term Missions

Short term missions or quests move the story forward. Missions and quests give the participants things to do. In the case of Zombies Run [1], runners are given specific quests to leave the safety of their human compounds and run out into the post-apocalyptic zombie-filled world in order to find necessities such as batteries, clothes, and water.

In a game such as golf, the over-arching goal is to complete the course with the least amount of strokes. But the individual holes on the golf course could be considered to be the short term missions or goals which move the game forward.

In the Expedition to Phobos and Deimos, the students were given specific missions or assignments. The missions given to the students included assignments such as 1) create a blog for the captain of the spaceship 2) create a wiki where passengers can collaborate on keeping a record of their journey 3) create a chat room so passengers can easily contact each other. The written documents given to the students were branded with the artwork of the over-arching story. The written documents gave clear, consise assignments and showed which badges (Badges will be disscussed in detail in Section 5.5) could be earned.

5.3 Points

Points are a numeric measurement of achievement. Point systems are found often in business loyalty programs. Frequent flyer miles are a point system which attempts to keep flyers loyal to one airline [26].

Consider a typical educational environment in which a student might earn the following marks on three assignments: 85%, 90%, and 83%. In a gamified educational environment, students would earn points for assignments. In this example, the student could earn 1700, 1800, and 1660 points for those same assignments. In this simple example, the traditional percentage was multiplied by 200 giving an absolute value of points. The Android application, however, showed the ever increasing accumulation of points. So the student would see 1700, 3500 (which is 1700 plus 1800), and finally 5160 (which is 1700 plus 1800 plus 1660).

In addition, points were awarded for behaviour which the author wished to encourage. This included points for taking part in discussions, points for assisting other students, points for assisting with administration of classroom wiki, etc.

These points would arrive on the Android application in the normal Android notification drawer and could be easily viewed by the student using the Android application as can be seen in Figure 1.

Figure 1: Example of points

5.4 Leaderboards

Leaderboards provide rankings between participants. Many sports and games have leaderboards including golf and soccer tournaments. The music industry has a leaderboard facility with the ranking of popular hit music. Modern electric cars also can have leaderboards. The new Nissan LEAF has a digital tree on the dashboard which increases or decreases in size depending on whether or not the driver is operating the car in an ecologically friendly manner. The trees are then ranked against other drivers [18].

The Android application provided a leaderboard ranking the students against each other. This facility could be considered to be controversial or, perhaps, an invasion of privacy. For that reason, the Android application provided an option where students could opt out of the leaderboard if they so desired. In such cases, the students would continue to receive points and badges. They could also see their own ranking against other students. But other students could not see their ranking. A sample of the leaderboard can be see in Figure 2.

Figure 2: Example of Leaderboard

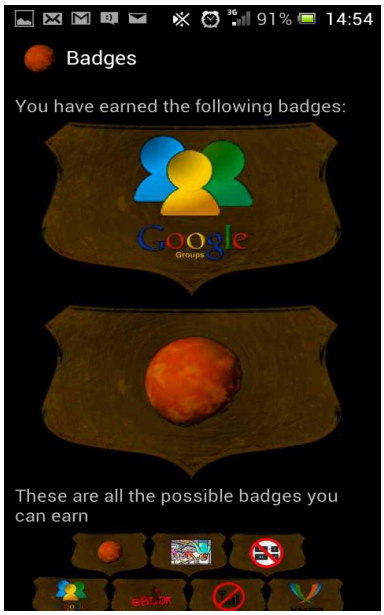

Figure 3: Example of badges

5.5 Badges

Badges are a visual representation of achievement. The military has been using badges and medals for thousands of years [16, 23]. Credit card companies supply cards in different colours as an indication of the customer's creditworthiness. Organisations such as Boy Scouts and Girl Scouts award badges when participants learn certain skills. Primary and secondary schools which require that the pupils where uniforms often award badges or pins which can be displayed on school blazers. Even university level education uses different coloured graduation gowns depending on whether the graduate is earning a bachelors degree, masters degree, or PhD.

On the Expedition to Phobos and Deimos, every short term mission gave students an opportunity to earn one or more badges. These badges were visual representations of the topic which was covered in the mission. The badges were shown on the printed materials encouraging students to earn these badges. The badges then arrived on the Android appliction using normal Android notifications.

Examples of badges can be seen in Figure 3

5.6 Leveling

If the over-arching story could be considered to be long term goals and the missions be considered to be short term goals, then leveling provides intermediary goals. Traditional education systems already provide a leveling system and once per year students are leveled-up or promoted from grade one, to grade two, and on to grade three, etc. The military provides a leveling system and participants can move through the military ranks. Even health insurance companies provide leveling system. Discovery Health's Vitality health improvement program allows participants to move through the levels as they earn points for healthy behaviour [23]. Boy Scouts and Girl Scouts also move through a ranking system.

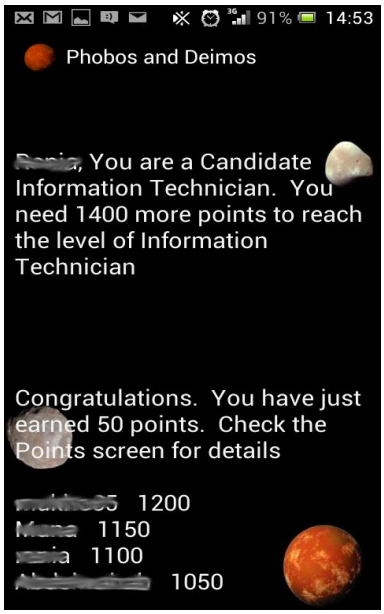

Figure 4: Example of leveling

On the Expedition to Phobos and Deimos, students started at the level of Candidate Information Technician. As they earn points, they could get promoted through the ranks culminating with Chief Information Technology Officer. Another important feature is that the leveling must always provide the student with information about how many more points are necessary in order to attain the next level.

The leveling notifications and requirements were available on the Android application. An example of this can be seen in Figure 4.

5.7 Onboarding

Many organisations have onboarding experiences. Nursery school is an onboarding experience for traditional education where children are taught the rules of how education works – ask permission, raise your hand, take turns. Boot camp is an onboarding experience for the military where soldiers are taught the rules of the military – polish your boots, keep your gun clean. Modern computer games have onboarding experiences where players learn the rules of the game while playing in a sandbox or protected area.

On the Expedition to Phobos and Deimos, the first week of the course was an onboarding experience. Students earned points for just about any positive action on the course. There were three potential badges which could be earned. This onboarding week ensured that all students knew how the Android application worked and ensured that they were aware that badges and points would arrive on their smart devices.

5.8 Engagement Loops

Engagement loops are mechanisms to re-engage with participants. Prior to the Internet, traditional book buying clubs sent out flyers every month to inform participants of new books which might interest them. Now with the Internet, businesses such as Amazon send out email to customers with suggestions of new books which might interest them.

The Expedition to Phobos and Deimos had two different engagement loops. One was the normal Android notifications and the other was a mailing list linked to the Google email address on the Android phone.

Whenever students earned points or badges, they were sent notifications. In addition, however, whenever students earned badges or leveled up, then all students received notifications and asked to congratulate the student who had earned the badge or leveled up. This encouraged all students to re-engage with their studies.

5.9 Mechanics Summary

Gamification is the use of game mechanics in a non-gaming environment in order to solve problems and engage users. Examples of game mechanics include physical objects such as balls. Examples of game mechanics also include non-physical objects such as rules and ideas. For example, taking turns, earning points, and earning badges.

This research used eight game mechanics: over-arching story, short term missions, points, leaderboards, badges, leveling, onboarding and engagement loops. These eight mechanics were embedded into a class and embodied on an Android application.

6. RESULTS

In 2013 when this course was taught without any gamification, nearly 80% of all homework was returned late. In 2014 eight game mechanics were embedded in the course and an Android application was created which embodied the game mechanics.

The results are very encouraging. Over the course of the entire semester, 60% of the homework was actually returned before the actual due date. A side effect of this statistic was that the students were now better prepared for group discussions and the over all quality of the course improved.

In email based discussions with the students after the course, they all confirmed that the gamification aspect was a success. The students were not first language speakers and their English is not perfect but their comments confirm that gamification has a positive place in education:

> I love it and always look at the board to win higher points
>
> when I see XXXX do the assigment and she earns the badge I told to my self why I didn't do my work.

One female student reported that her pre-teen son looked at his mother's cell phone every morning to see if his mother was still at the top of the class. In this case, gamification turned the table on the parent-child relationship of who was encouraging whom to study well.

Perhaps the most interesting result, however, occurred after the final examination. There was one mission (or assignment) which had been substantially more difficult than the other missions. After the final examination, students asked if they could continue to work on that last mission in order to obtain that last badge.

7. FUTURE WORK

This was the author's first experiment in gamification. There are additional game mechanics which could be incorporated and if the author is invited to teach this module again, work may be done to incorporate additional mechanics.

In some games, players take turns. In other games, players strive for possession of the ball and try not to take turns. For example, in tennis, one player hits the ball and then the other player hits the ball. In American baseball, one team is up to bat and then the other team is up to bat. This contrasts with a game such as soccer where it could be possible for one team to gain control of the ball for the entire duration of the game.

In the course described in this paper, there were a number of extremely competitive students. Whenever the author offered additional points for some additional research, these students

jumped at the opportunity to do the additional research or work in order to earn more points. Perhaps some turn-taking mechanism could be implemented in order to encourage less competitive students to also volunteer for such opportunities.

In the course described in this paper, the author and the students were in two different countries. However, if they were in the same country or if this were a face-to-face class, perhaps the points could be redeemed for some benefit or classroom privilege. In a face-to-face class, perhaps points could be used to excuse absences from class. If financial sponsors could be obtained, perhaps points could be used to purchase textbooks or a token item such as a USB stick.

8. CONCLUSION

Gamification is the use of game mechanics in a non-gaming environment in order to solve problems and engage users [10, 11]. Common game mechanics include points, leaderboards, and badges.

In 2013, the author was invited to teach an Information Technology over view course using Internet facilities. The author and the students were in different African countries and communicated using a wide variety of Internet technologies. In that 2013 experience, nearly 80% of the homework assignments were returned to the author late.

In 2014, the author was again invited to teach the same course. In an effort to pre-emptt the late homework return, eight game mechanics were added to the module keeping the remaining content the same between the two years. The eight game mechanics were over-arching story, short term missions, points, leaderboards, badges, leveling, onboarding and engagement loops. The eight game mechanics were embodied on an Android application which the students could download onto their personal devices. In 2014, there was a dramatic improvement in homework returns with 60% being returned before the actual due date. In addition, after the final examination for the 2014 course, students still worked on assignments for which they had not yet received badges.

Internet based education (including e-Learning and MOOCs) suffer from high dropout rates [5, 15, 22]. The results from the research in this paper, however, show that gamification can be used to successfully engage students in distance education.

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Using Video Podcasts to Teach Procedural Skills to Undergraduate Students

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ABSTRACT
Literature suggests that video podcasts could have a valuable role to play in teaching problem-solving skills through the demonstration of worked examples. This paper describes how supplementary video podcasts were introduced in an undergraduate course that had previously relied on lecture-based teaching of practical Excel skills, and then analyses student perceptions and performance based on student feedback combined with class marks. The results show that video podcasts positively enhanced the students' learning experience; nevertheless, students felt that traditional face-to face lectures should still be retained, with podcasts being used to provide additional support. The podcasts made no apparent difference to students' academic performance.

Categories and Subject Descriptors
K.3.2 [**Computer and Information Science Education**]: Information Systems Education.

General Terms
Performance, Design, Human Factors.

Keywords
Video, podcasts, blended learning.

1. INTRODUCTION
In distance learning programs, lectures are increasingly being delivered in the form of multimedia files that are distributed over the internet in digital format [16, 19, 25]. [To remain consistent with terminology that has been widely used in the literature, such educational multimedia files have been referred to in this paper as 'podcasts', despite the fact that in most of the cases cited, the files are being accessed through the campus Learning Management System (LMS) rather than via an RSS feed.] Online lecture delivery is closely aligned with current teaching practice which is predominantly lecture-based, while at the same time making it possible to extend the reach of the university to an increased number of geographically dispersed students [6]. However, the role of podcasts within traditional campus settings is not as clear.

SACLA 2015, 02-03 July, Johannesburg, South Africa

The convenience of replacing lectures with anytime, anyplace access to recorded material is offset by decreased opportunity for asking questions, interacting, and engaging more deeply with the material. Recent research [10, 11, 16, 18, 19] suggests that podcasting is most effective when it is used in a supplementary rather than a substitutional role, in which case it serves to augment the lecture and encourage deeper understanding of key concepts or practices. An area where supplementary podcasts could be of particular value is in the teaching of procedural skills, which depend on the understanding of basic facts and concepts as well as the logic that is required to apply them correctly in a given situation.

This paper starts by reviewing the role of podcasting in tertiary education, before describing a blended learning intervention where video podcasting was used to enhance the teaching and application of practical Excel skills. Based on data collected through a student feedback survey together with classwork and examination results, we then analysed student perceptions and performance in order to answer the following research questions:

In the context of teaching procedural skills to undergraduate students

a) Does the provision of video podcasts enhance the students' learning experience?

b) Does the provision of video podcasts render the traditional lecture unnecessary?

c) Does the provision of video podcasts have a positive effect on student performance?

The findings will shed light on the role that can played by video podcasts in teaching procedural and problem-solving skills, while at the same time maintaining realistic expectations of what can be achieved through the use of educational technology.

2. LITERATURE REVIEW
For universities, podcasting holds the promise of catering for increased student numbers without a concomitant increase in resource costs [8]. However, researchers warn against the adoption of multimedia technology for its own sake without a sound pedagogical basis [16, 18, 22]. This section of the paper provides an overview of how podcasting is being used in tertiary education, in order to derive an pedagogically sound approach to using video podcasts for teaching procedural skills to undergraduate students.

Podcast use in education is predominantly audio-based, to accommodate file size restrictions and bandwidth constraints for storage and downloading [4, 6, 21] and to provide increased

mobility of access [6, 13]. Audio recording also remains a popular option with academics because the technology involved requires less expertise to use [4, 13, 21], although the end result can sometimes be frustrating for students: for example when reference is made to a diagram that is not visible [15]. Despite the fact that video podcasts have now become easier to create and distribute, they are still mainly used to record lectures by combining a soundtrack with powerpoint slides. While this is convenient for educators in content-heavy courses, it can encourage passive or rote learning and decreased engagement with lecture material [20]. In addition, since students are unable to ask questions the lecturer cannot gauge their level of understanding and is not aware of difficulties or misconceptions [19].

The use of podcasts for instruction can be categorised as either substitutional or supplementary [8]. Substitutional podcasting replaces the traditional face-to-face lecture with a recorded equivalent, to be downloaded and watched by students in their own time. In fully online courses this is perceived as being a more effective mode of communication than the distribution of printed notes, but when given the option, students prefer face-to-face lectures which have the additional element of lecturer interaction [10, 16]. Where podcasts are used for campus-based teaching, students prefer them to be used in combination with face-to-face lectures [11, 15, 19], for example in order to present facts and concepts prior to class meetings so that lecture time can be used for interactive class discussions [5, 18].

The alternative to substitutional podcasting is supplementary podcasting, where recordings are used to augment lecture content and enhance student understanding. There is widespread consensus that this approach is more effective than substitutional use [8, 15, 25]. In this case lectures are used for the initial delivery of content, providing an opportunity for the lecturer to introduce, explain and discuss key concepts, and ask and answer questions to clarify misunderstandings [18, 19]. This interaction with the lecturer can also help to engage and motivate students [14, 21]. The supplementary podcast is subsequently used to highlight important points, explain difficult concepts, or deepen understanding by discussing examples and application [2, 8, 9, 20, 21]. In this way the student is exposed to a number of different perspectives, reinforcing learning.

A substantial body of research has highlighted the advantages to be gained from the use of podcasts. The most commonly reported benefits relate to the ability to review, revise and make up missed work [6, 10, 14, 20], followed by the convenience of access at any time and from any location [10, 14, 18, 19]. The availability of recorded content for later reference allows students to focus on interaction and active listening in class rather than note-taking [14, 20]. Students also report improved understanding of content [11, 14, 15, 21] and in particular English Second Language (ESL) students appreciate the opportunity to familiarise themselves with new terminology and pronunciation [1, 9, 10, 18, 21, 21]. Although a negative impact on lecture attendance following the introduction of podcasts has been reported by Deal [5], the majority of studies on podcasting use have not found the decrease to be significant [6, 10].

With regard to the impact of podcast use on student performance, Schreiber [19] has suggested that the combination of visual and auditory media enhances learning; while students generally perceive that podcasts have enhanced their understanding of lecture material [10, 18, 20]. However, analysis of student performance based on course assessment has provided very little evidence of a positive relationship between the use of podcasting and improved student performance [8, 19, 21]. Karnad [10] points out that high-achieving students generally make use of both face-to-face lectures and podcasts, and posits an underlying connection between conscientious students and high grades. Furthermore, the wide variety of research contexts, academic disciplines, and ways in which podcasting is used, make it difficult to generalise about the effect of podcasting on academic performance.

At the same time as institutions are being pressurised to replace face-to-face lectures with podcasts in order to reach a larger numbers of students [5], there is growing awareness of the need to shift away from the view of multimedia as a delivery system and to pay more attention to its role in facilitating instruction and meeting the needs of students [16, 20, 22]. The design of blended learning interventions must be closely aligned with pedagogical objectives if the desired outcomes are to be achieved [17]. According to Thomas [22:39]: "Successful blending requires an understanding of the pedagogical attributes and affordances of new and emerging learning technologies, the most desirable aspects of face-to-face teaching and the ways in which these aspects can be appropriately integrated". He emphasises that technologies should be seen as cognitive learning tools rather than instructional media, and should be implemented with the goal of helping students to facilitate cognitive processing leading to knowledge construction rather than reproduction.

Cognitive load theory suggests that constraints on working memory interfere with the ability to transfer large amounts of information into long-term memory [7]. Algarni et al. [1] found worked examples to be an effective form of scaffolding when teaching mathematics to ESL students at tertiary level; by directing attention to the steps needed to solve a particular problem, cognitive load was reduced and students were better able to cope with the added linguistic challenge. Similarly, Wagner et al. [23] found a significant positive effect on skills transfer after students had worked step-by-step through a comprehensive set of increasingly complex worked examples based on the same statistical test. However neither of these studies made use of learning technology, with the Wagner et al. study being based on a text document including twelve worked examples, while the Algarni et al. study simply surveyed student preferences.

Multimedia recordings would appear to be an effective medium for developing practical skills through the demonstration and practice of worked examples, which would allow students to review and process information in smaller chunks for more effective transfer [3, 23]. Kennedy and McNaught (cited in [22:48]) note that "carefully designed computer-based cognitive tools can scaffold learning by modelling complex environments or expert problem solving strategies", and it has been suggested that problem-solving video podcasts should be viewed as a distinct teaching strategy [11]. In an introductory programming course, pre-recorded mini-lectures targeting specific topics were used as a supplement to conventional lectures in an attempt to help students grasp the basic principles of algorithmic problem-solving [21]. Although student grades did not show improvement, students' self confidence increased and faculty spent less time answering student queries. In a similar intervention, video tutorials were used to help students develop a deeper understanding of fundamental chemistry concepts which would enable them to work out mechanisms from first principles [2]. Subsequent student responses indicated that following the lecturer's train of thought and understanding the approach to use was as valuable to them as grasping the underlying mechanism.

In a more recent paper, Kay [12] notes that few studies discuss use of video podcasts for presentation of worked examples, and proposes a framework for the development of effective video podcasts. This framework is based on four key components:

- Establishing context – before delving into a solution, time needs to be spent on explaining the nature of the problem, understanding what is being asked, and identifying key elements required to solve the problem.
- Creating effective explanations – breaking the problem into meaningful cognitive steps, explaining the reasoning behind each step, and providing visual support.
- Minimising cognitive load – providing clear explanations, using a well organised layout, and highlighting the problem area that is being addressed.
- Engaging students – through conversational speech delivered at an appropriate pace, by minimising extraneous information, and limiting the video length to a maximum of 10 minutes.

These principles were applied by the author in developing a series of problem-solving video podcasts as described in the next section of this paper, which were used to supplement face-to face demonstration lectures with short video recordings of worked examples.

3. METHODOLOGY

3.1 Context of the study

The podcast intervention described in this paper was implemented within a three-week Decision Support Tools module taught in the first semester of a second-year Information Systems course at Rhodes University. In this module students are taught the basic principles of applications used for business decision support, such as OLAP, data mining, model based DSS and expert systems. In weekly practical sessions supervised by postgraduate tutors, students are expected to complete a set of scenario-based practical exercises and submit them for marking. These exercises are designed to reinforce theoretical principles at the same time as developing Excel skills; for example, OLAP principles are illustrated using data manipulation and pivot charts, while DSS is illustrated by developing estimation models and doing 'what if' analysis.

Friday lectures are used to give students an overview of the next week's practical exercises and the Excel functions that will be needed to solve them. Due to the size of the class (about 300 students) it is not possible to lecture in a computer lab, and so the lecturer demonstrates and explains the relevant Excel functions in a lecture theatre using a data projector connected to a computer. In previous years students have struggled to later apply the procedural skills that were demonstrated in the lecture: the "what" of the underlying calculation logic, the "why" of knowing which of several approaches is best suited to a specific task, and the "how" of using Excel. As a result, students have frequently been tempted to copy the solution from a classmate rather than trying to work it out on their own.

In 2014, the lecturer decided that in addition to usual pre-prac demonstration lectures held on Fridays, she would record a number of short video clips each covering one or two of the key Excel functions that would be used in the next week's prac. The videos were designed in keeping with Kay's [12] framework for developing effective instructional video podcasts, for example each video focused on a specific function or set of related functions so that students would be able to selectively watch only the material they needed help with; the audio track was used to explain the logic and principles being applied; and none of the videos was longer than a maximum of 10 minutes.

The combination of pre-prac demonstration lectures and supplementary videos worked as follows:

The pre-prac demonstration lecture started with an overview of the scenario on which the next week's practical exercises were based, and outlined the types of problems that students would be expected to solve. The actual demonstration then focused on the more complex functions that students would need to use, since the length of a lecture period is only 45 minutes, compared with 3 hours for each practical session. To prevent students from copying answers without having understood the underlying logic, the spreadsheet used for the lecture demonstration and videos differed slightly from the spreadsheet and problems used for the actual practical session. Videos were recorded using Camtasia Studio 8 and saved in mp4 format before being uploaded to the course LMS.

Altogether nine video podcasts were recorded. The business scenario and accompanying prac exercises were available to students as a separate text document on the LMS, and the initial podcast simply reviewed the structure of the demo spreadsheet and highlighted areas where the demo spreadsheet differed from the one that students would be using in their practical sessions. Four podcasts were then recorded to cover the first week's practical exercises, and another four for the second week. The Camtasia software allowed for live recording of the Excel screen including cursor movements, while the lecturer 'thought out loud' in terms of clarifying what needed to be calculated in order to complete each exercise, identifying an appropriate formula structure and Excel function(s), demonstrating how the formula was constructed and used, and highlighting potential problems such as forgetting to use absolute referencing before copying a formula. The podcasts were uploaded to the LMS ahead of the corresponding practical sessions, and students were reminded to take headphones to the lab with them so that they could access the recordings if needed. Although tutors were also available in the lab to provide support, they were encouraged to first direct students to the video material in an attempt to develop the student's understanding and confidence.

3.2 Survey and data collection

The use of supplementary podcasts was one component of a more general blended learning intervention that was implemented during the Decision Support Tools module (described in more detail in [17]). At the final practical session, the lecturer asked students to complete a short survey asking their views of the various blended learning tools and approaches that they had been exposed to during the module. Students were informed that their participation was voluntary, and that although the survey was not anonymous, the identities of individual respondents would not be revealed.

The primary purpose of the survey was not to collect quantitative data, but rather to identify which aspects of the intervention were perceived as being most effective, and to understand what value they offered to students. Responses were in the form of free-text answers of unlimited length, although some structure was provided within the questions to ensure that feedback was given about issues of particular interest to the lecturer. The following three questions were used to elicit feedback relating to the use of

video podcasts in conjunction with pre-prac demonstration lectures:

1. The final lecture of each week was used to give an Excel demonstration of the exercises for the next week's prac. Did you attend either of the prac demonstration lectures? If not, then why not? And if you did, then did you find them useful and/or easy to follow?
2. Video clips were provided on RUconnected to help you with the prac exercises. Did you watch any of them? If not, then why not? And if you did, then did you find them useful and/or easy to follow?
3. Do you think that having the video clips makes it unnecessary to give prac preparation lectures?

An online link to the survey was distributed to all 284 students registered for the course; 191 responses were submitted by students and downloaded by the lecturer into an Excel spreadsheet. After the final examinations had been written and graded, the survey responses were combined with students' practical and examination marks so that the impact of videos on student performance could be investigated. In addition, since a number of students did not indicate explicitly whether they had attended the pre-prac lectures, attendance data based on the survey responses was augmented from a physical register that had been taken at the lectures. To remove any risk of prejudice to individual students, the spreadsheet column containing student identities was deleted once the marks and attendance data had been added to each record.

For each response, the lecturer noted whether the student had attended any of the pre-prac lectures, whether they had viewed the videos, whether they had found the videos useful, and whether they thought that both lectures and videos were necessary. The free-text comments made by students were then analysed and common themes identified.

4. RESULTS

The students who completed the survey appear to be representative of the class as a whole (at least in terms of academic performance), since the average course result obtained by survey respondents (56.4%) and average course result obtained by all students (55.7%) were not significantly different. Where students did not explicitly state whether they had watched the videos, or whether they felt that both lectures and videos were necessary, any corresponding analysis was based only on the students who answered that specific question.

4.1 Analysis of survey data

Figure 1 illustrates the frequency of pre-prac lecture attendance and video use by students, as well as providing an indication of how useful students found these resources to be and whether they felt that both the lecture and the corresponding video support were needed.

- 159 out of 191 respondents (83%) had attended at least one of the three pre-prac demonstration lectures, and 88% of those students who had attended at least one pre-prac lecture said they found it to be useful.
- 22 students did not indicate whether they had watched any video podcasts; unfortunately video download statistics could not be retrieved from the LMS for technical reasons and so those students had to be omitted from analysis relating to video watching. 168 of the remaining 169 students (99%) said that they had watched at least one video podcast; and 100% of those who had watched at least one podcast said that they found it to be useful.
- 79 students did not respond directly to this question. 71 out of the remaining 112 students (63%) said that there was a need for both the videos and the lectures, while the other 37% felt that the videos alone were sufficient.

Analysis of the open-ended text responses revealed a number of recurring themes in line with those that had previously emerged in the literature.

- The usefulness of the pre-prac lecture for providing an overview of the problem context:

  I attended the lecture, they helped clarify the task at hand. I watched the videos, they helped even more by showing what needed to be done. No I think both the lecture and the videos need to be available because they focus on clarifying different things.

- The usefulness of the pre-prac lecture for student interaction and resolving queries:

  I attended the lectures and I made use of the video clips that were provided. I do not think the videos eliminate the incentive to attend lectures, in lectures you get to clarify whatever little query you may have, but the video will not.

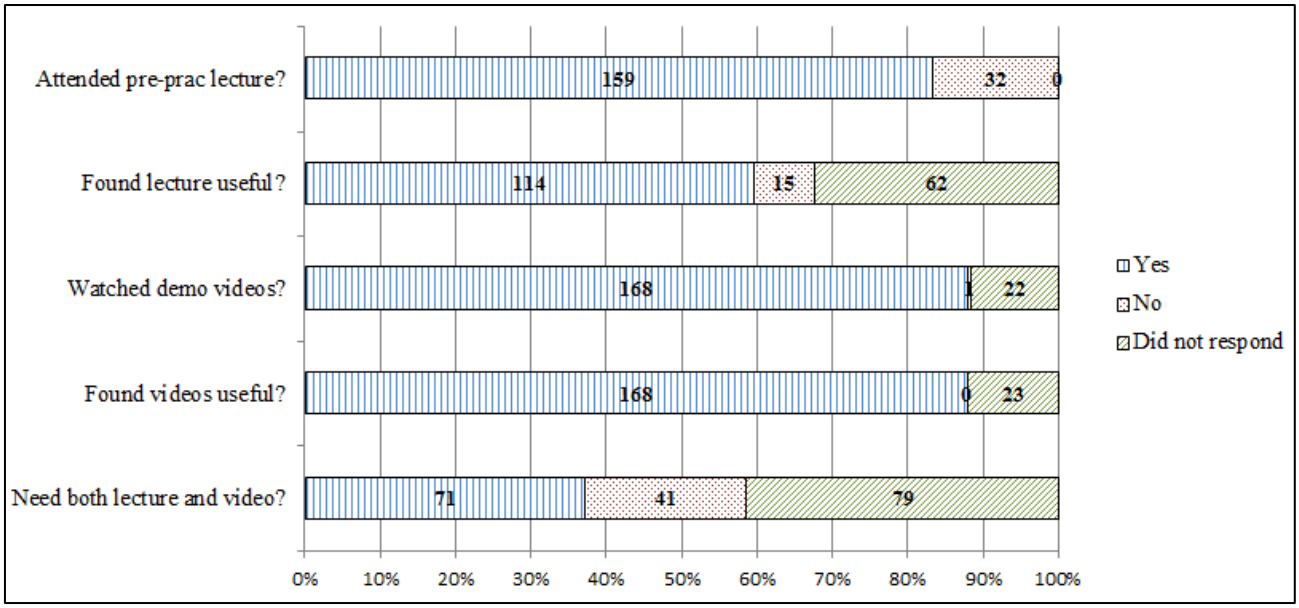

Figure 1. Quantitative analysis of survey responses (n=191)

- The usefulness of the video podcast for reviewing points that were missed during the pre-prac lecture:

  I attended all of the demonstration lectures and I found them useful even the video clips they helped me if there was something that I did not understand in class I would go to the video clip, it is necessary just incase someone dont understand in the lecture so that they can go back and find the way to figure out how to solve the problem

- The usefulness of the video podcast for listening to a section of work repeatedly to gain understanding:

  I do attend prac demonstration letures and I find them very useful. Vedio clips are there way to understand the prac because you can listen to them alone and repeat,pause and do what ever that will help you to understand what you are doing.

- The usefulness of the video podcast for allowing students to focus on active listening during the lecture rather than taking notes:

  I attended all the prac demonstration lectures and all I did was listen so that I can understand. this was because I knew that the video would help explain what I didn't catch on.

- The usefulness of the video podcast for catching up work that had been missed through lecture non-attendance:

  I didn't attend, I was late for classes. I watched the videos and they were very easy to follow and helpful

- The need to provide both pre-prac lectures and video podcasts:

  The friday lectures are very useful because they prepare us for our pracs, easy to follow. I loved the videos, they answer every question that one would have asked in the prac, they are useful and they just add on to the friday lecture, they make things clear

Slightly more than a third of the survey respondents felt that the video podcasts made pre-prac demonstration lectures unnecessary, with reasons ranging from knowing the work already, to feeling that they could depend on the videos for any support they needed, to the soporific effect of lectures.

> *The prac demonstration lectures were useful, but i think they could have been used for something else. I say this because for me personally the video clips explain the prac exercises perfectly and the advantage about them is that i can stop, rewind and forward when i want to. Therefore, i go with the video clips than the lecture.*
>
> *Video clips were extremely helpful,and i did not attend the demonstration lectures as i knew the videos would be adequate*
>
> *I did not find the lectures useful they made me fall asleep. I prefer the videos.*

Overall, the class responded extremely positively to the combination of holding pre-prac demonstration lectures supplemented with video podcasts:

> *The videos are amazing it was like having a private lesson one-on-one with the lecturer. I think the videos add quality to the prac content and the prac preparation classes were equally as beneficial.*

4.2 Impact on academic performance

Impact on academic performance was evaluated based on two metrics: the mark obtained for the weekly Excel practical exercises (at which video support and tutor assistance were available to students); and the mark obtained for Excel-related questions included in the final examination. The mark obtained

for theory questions from the same module (i.e. not based on Excel) and the overall course result for each student were also included in an attempt to clarify the effect of the lectures and videos on students' understanding of practical work through comparison with their theory mark and the their overall course mark.

As shown in Table 1, students who attended the pre-prac lectures and also watched the video podcasts achieved the highest marks for the weekly practical exercises, for the exam theory questions from the same module, and for the overall course result. Students who did not attend the pre-prac lecture obtained the lowest marks across the same set of assessments. This would appear to support the idea that stronger students are most likely to make use of all available resources. Interestingly, students who did not attend any pre-prac lectures performed worst on the weekly practical exercises and had the lowest overall course result; while students who thought that the pre-prac lecture was unnecessary performed worst on the practical questions asked in the final examination.

The small variation in marks across most subgroups of survey respondents can probably be explained by the substantial number of students who responded similarly to multiple questions (for example, 88% of students who attended the pre-prac lecture also watched the video podcasts).

Table 1. Average student results grouped by survey responses

	n	Weekly practical exercises	Exam practical questions	Exam theory questions	Overall course result
Attended pre-prac lecture	159	75.8%	51.7%	52.0%	56.9%
Watched video	168	75.1%	52.1%	52.9%	56.9%
Attended lecture AND watched video	140	76.7%	51.4%	52.9%	57.5%
Did not attend pre-prac lecture	32	67.1%	54.0%	51.2%	53.8%
Think pre-prac lecture is unnecessary	41	73.9%	49.6%	52.7%	55.2%
All survey respondents	*191*	*74.3%*	*52.1%*	*51.9%*	*56.4%*
Entire class	*284*	*71.6%*	*50.9%*	*49.5%*	*55.7%*

5. DISCUSSION

The most commonly reported benefits of podcasting that emerged from the literature review were the ability to review or revise lecture content or to make up missed work; the convenience of access at any time and from any location; the freedom to focus on interaction and active listening in class rather than note-taking; improved understanding of content; and the opportunity for ESL students to familiarise themselves with new terminology and pronunciation.

Student responses to the feedback survey closely echoed the factors that had emerged in the literature review, and pointed clearly towards an enhanced learning experience. They described the personal benefit of being able to make up for missed lectures; they appreciated that if they failed to grasp a concept the first time round they could go back and review it; and many remarked that they had learned far more from watching the videos after the lecture than they did from the lecture alone. A few students mentioned that they had been able to listen more attentively during lectures because they weren't trying to take notes at the same time. It is surprising though that in a class where the majority of students are second-language English speakers, nobody raised the point that video use made it easier to overcome linguistic challenges.

The quantitative analysis of lecture attendance and video watching suggests a slight but insignificant positive relationship with academic performance, in that students who participated in both lecture attendance and video watching achieved the highest marks for the weekly practical exercises. However, the fact that the same group of students also achieved the highest marks for the exam theory questions and for the overall course result, lends support to the hypothesis raised by Karnad [10] that conscientious students are most likely to make use of all the resources available to them and are also most likely to achieve the highest results. Perhaps a more interesting finding is that students who did not attend the pre-prac lecture did worst on the weekly practical exercises, while the 44 students who thought that the video recordings made it unnecessary to attend pre-prac lectures were the only group to score below 50% on the practical questions asked in the examination.

Taken overall, the fact that 83% of the survey respondents attended the pre-prac lecture and 88% of those found it useful provides strong support for retaining the lecture and using video material as a supplement rather than a substitute. Similarly, the overwhelmingly positive response to the video podcasts suggests that they are worth continuing despite the considerable effort involved in video production. Even if the podcasts did not have a measurable impact on academic results, students made it clear that having this resource available to them made a definite difference to their Excel skills competence.

> *The pracs are not too difficult. The thing that takes the longest is either understanding a concept, or figuring out what formula you have to use for which question. The excel pracs struck me as really useful, because you are teaching us skills we can use hands on in the real business world.*

6. CONCLUSION

Literature suggests that video podcasts could have a valuable role to play in teaching problem-solving skills through the use of worked examples. This paper describes how supplementary video podcasts were introduced in an undergraduate course that had previously relied on lecture-based teaching of practical Excel skills, and goes on to discuss the subsequent analysis of student perceptions and performance.

With regard to the first research question (*Does the provision of video podcasts enhance the students' learning experience?*) the answer appears to be an unequivocal 'Yes'. This is very gratifying

in light of the effort required to produce the podcasts, and provides strong motivation for continuing with similar work in the future.

With regard to the second research question (*Does the provision of video podcasts render the traditional lecture unnecessary?*) the answer appears to be an equally strong 'No'. Most students felt that both resources were needed; and those students who felt that the face-to-face lectures could be discontinued turned out to be the weakest students academically, who would probably benefit from lecture attendance.

With regard to the third research question (*Does the provision of video podcasts have a positive effect on student performance?*) the answer appears to be an uncertain 'No'. Although the students who watched the video podcasts in addition to attending lectures obtained the highest marks for practical work, they were in fact top students across the course as a whole even though no other modules offered video support. One should probably conclude from this that strong students are likely to take advantage of additional resources such as podcasts, rather than inferring that they are strong students because they watched podcasts.

In closing, we would like to suggest that many opportunities exist for further research in this area; particularly, given our South African context, in understanding the potential value of supplementary podcasts for students whose home language is not English, or who enter university inadequately prepared for the academic challenges that face them.

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An Ecological Model of the Information Behaviour and Technologies of Undergraduate Students in a South African University

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ABSTRACT
A first-year undergraduate course in Information Systems in a South African university includes an opportunity for students to reflect on their own use of information and information systems. Their reflections provide data about the technologies and tools that they use to find and manage everyday life information as well as academic information, and about the sources of information they draw on. This paper analyses the data and reports on the technologies in use and the sources of information that students engage with. We make use of the ecological model of information seeking and use developed by Williamson [19] to make sense of the diversity of information sources and the relationships between students and these information sources. The study offers insights into the context and behaviour of undergraduate students that will be of interest to those involved in designing and delivering undergraduate programmes.

Categories and Subject Descriptors
H.1.1 [**Models and principles**] Systems and information theory
H.3.3 [**Information systems**] Information storage and retrieval
H.4.2 [**Information systems applications**] Types of systems

General Terms
Management, Human Factors, Theory

Keywords
Personal information system; information behaviour; undergraduate students; information technology; information seeking; information sources; personal informatics

1. INTRODUCTION
"Fundamentals of Information Systems" is a one semester course offered in the first year of the Bachelor of Commerce (B.Com) degree at the University of the Witwatersrand. It is a compulsory course for all B.Com students and an elective course for students from other faculties, with the aim of teaching them enough to be an "educated end-user" of information systems.

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During 2013 the course underwent a major change in approach to introduce more of a systems focus and to move away from the traditional presentation of information systems by building up from hardware components; networking, databases and software to business concerns [18]. As this course is focused on students who will go into business, non-profits or the public sector in a range of capacities, our goal was to produce users of information systems who will understand the role of information systems in organisations, be familiar with the key elements of an information system, and be able to engage constructively with IS professionals in selecting, designing or implementing information systems in the workplace. The course also encourages students to think about the effects of technology on the individual and on society.

In order to manage the variety and volume of information associated with university studies, students need to develop complex personal information systems that incorporate physical and digital elements [13]. Thus a secondary aim of the course is to address the very different levels of exposure to information technology and information sources that students have when arriving at university and to ensure that those who are not experienced in using these tools quickly learn enough to be able to make use of them during their studies. To this end, the course includes an exploration of personal information systems, during which students are introduced to technologies and information sources that might be of use to them in their studies.

As university lecturers, we are interested in the information behaviour of students – how they source, store, manage and use information – to inform our teaching. We teach students who are "millennials", born between 1979 and 1995 [14] and regarded as skilled in and accepting of information technologies. However, these students' information behaviour has been informed by instant access to information selected chiefly for its entertainment value and they are arguably ill-equipped to access academic information [4]. In particular, students newly arrived at university need to be able to access knowledge that they do not yet know that they lack and a personal information system that facilitates this would benefit them.

From student assignments conducted during the course we have gathered insights into what information technologies and information behaviours students use. Our analysis of this information provides the basis for proposing an ecological model of students' information behaviour and gives insights that will be useful for the design of university teaching programs.

2. PERSONAL INFORMATION SYSTEMS
Research into personal information management began in the 1960s with studies that focused on how academics and researchers organised their information gathering and storing activities [16],

[17]. The term *personal information system* was used in the 1980s to describe the sources of information and the information gathering practices of individuals, and particularly managers, following Mintzberg's study of the nature of managerial work and how managers made use of information to inform their decision-making [12]. Around the same time, studies emerged that examined personal information management in computerised contexts [5], [7].

More recently, the term personal information system (or personal informatics) has been used to mean an information system that stores personal information, for example about one's health, that is used by individuals for self-improvement (for example [9], [10]). The term personal information system in the former sense has since been largely replaced by the term *information behaviour*. In library and information science the term information system was replaced by the term *information-seeking behaviour* because "behaviour is observable" [21, p34] and later by the term information behaviour to encompass the behaviours associated with the storage, management and use of information.

In the Fundamentals of Information Systems course we introduce students to the idea of personal information systems in both senses. We prefer to use the term personal information system to describe students' information behaviour because we want students to draw analogies to business information systems, recognizing that people, processes, places and technologies form part of both. We also make them aware of the second use of the term personal information systems. In a sense though, a student's personal information system (information behaviour) is also a system that stores personal information, or at least information that is highly personalised in terms of what is gathered and how it is organised and used. This system does have a goal of self-improvement in the broadest sense, since it will be used to manage information pertaining to all aspects of life.

3. ECOLOGICAL MODEL OF INFORMATION BEHAVIOUR

Williamson's ecological model of information seeking and use considers the use that an individual makes of a range of information sources as being influenced by "ecological" elements. The model was influenced by a view of people as "self-creating, but within contexts" [20, p130] where those contexts might include biological, social, economic and physical circumstances. The emphasis is on the relationship between the individual and the information sources, including institutional sources, media and personal networks.

Williamson's model builds on Bates' "integrated model of information seeking and searching" [3] in that it encompasses both purposeful, or goal-directed information behaviour and what is termed *incidental information acquisition*. In the former, the individual is aware of an information need and sets out to find information to meet that need. In the latter, the individual becomes aware of information as a result of being in a place or some interaction or engagement, rather than in a directed fashion [20]. Bates argued that the majority of knowledge is acquired through "being aware, being conscious and sentient in our social context and physical environment" [3, p4].

This model of information behaviour aids us in understanding the behaviour of undergraduate students because it acknowledges the diversity of contexts that students operate in and also the range of information sources that they access. Later in the paper we present an adaptation of this model, including the information sources that we found in our study and the contexts that have been found to be relevant to undergraduate students.

4. RESEARCH QUESTIONS

Our interest lies in understanding the technologies employed and the information behaviour of students entering university and the role that university resources played in their personal information systems. This paper addressed the following research questions:

1) What technology devices do students use to access and manage information?
2) What sources of information do students use?
3) To what extent do students use the information resources provided by the university?

5. DATA COLLECTION

In the first two weeks of the Fundamentals in Information Systems course, students are encouraged to reflect on the information tools (both manual and electronic) that they use to find and manage information and to explore technologies and applications that they may want to use. Students share information about their favourite information tools and how they use them through an online forum.

Students are also asked to draw a "rich picture" of their own personal information system. Rich pictures are a tool used in information systems to depict the complexities of information systems components and their relationships [1] and are one of the information systems tools that students learn about in this course. Students were asked to draw a rich picture depicting the different sources of information and the tools to access and manage information which they were currently using or intended to use during their university studies.

Pictures were submitted electronically in a variety of formats. Some were drawn using software tools such as Word, PowerPoint or Visio and submitted in software-specific or pdf formats. Some students constructed collages or drew pictures freehand and scanned or photographed the results, submitting them in pdf or jpg formats. An example of one of the pictures submitted is shown in Figure 1.

Students uploaded their pictures to the learning management system (LMS). In total, 325 pictures were collected in 2013 and 456 in 2014.

6. ANALYSING AND INTERPRETING THE DATA

For the purpose of this analysis, the pictures were downloaded from the LMS and identifying information (names and/or student numbers) was removed. Each file was renamed with the year and a unique number and saved in pdf format. The two data sets (2013 and 2014) were then imported into Atlas.ti for coding.

A millennial coder was employed to identify and code each item on each picture. The coder's brief was to identify the specific technology or application that was referenced in the pictures. It was important to use a coder who was familiar with the technologies and applications in use by the students and who was sufficiently at home online to be able to track down references (textual and graphical) to obscure applications and technologies.

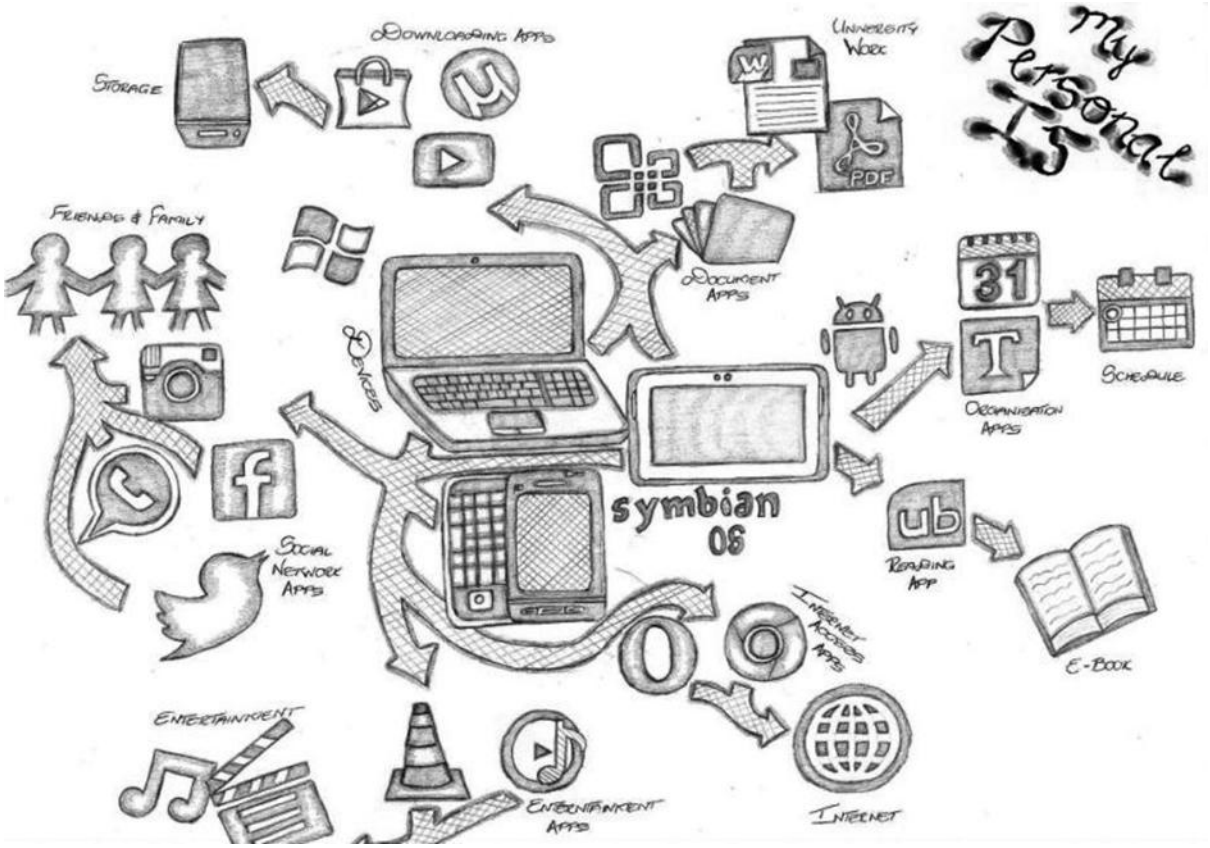

Figure 1: Example "rich picture" of a student's personal information system

Once this initial coding was complete, the researchers created code families to group together related concepts. For this paper, given our research questions, the focus was firstly on the technology devices used to source and manage information and secondly on the sources of information that students consulted. Technologies were fairly easy to group into categories such as cellphones, laptops, tablets and desktops.

Analysing the sources of information in the students' personal information systems proved more difficult and resulted in some debate as to what constitutes an information source. We distinguished between sources of information external to the student and tools used to store or manage information. The latter were not analysed for this paper. So, for example, an application used to manage tasks was not considered a source of information, despite the fact that students might consult such an application daily to identify tasks. Similarly, a book was considered an information source while files were considered tools for managing information. In analysing the information sources, we grouped sources based on the characteristics of the providers of information, in keeping with Williamson's model [20] but identified different categories than the original model.

In interpreting the data, there are two areas of uncertainly to be borne in mind. Firstly, although students were asked to depict the information systems that they were using at the time, they were also in the process of exploring new technologies and tools for information management. They were exposed to alternative technologies and information sources through viewing and commenting on other students' personal information systems. So in interpreting the data, it is important to remember that the pictures may to some extent represent aspirational information systems that students could see themselves using in the future. While this means that we cannot draw firm conclusions about the information system that the students were using, we believe that the data still gives a fair reflection of students' information behaviour.

Secondly, for most of the students this data was collected in the 2nd and 3rd weeks of the start of their first semester of study. This means that their personal information systems may have reflected more of their concerns with social information which would have been a priority during the recent long vacation following the end of school. On the other hand, the data may also have been biased towards the information that they would need for their university studies as they were freshly arrived in the university context and actively concerned with how to navigate it. Without further investigation it is difficult to know to what extent these biases are present in the findings.

7. WHAT TECHNOLOGY DEVICES DO STUDENTS USE TO ACCESS AND MANAGE INFORMATION?

Table 1 shows the frequency with which different devices appeared in the students' pictures in 2013 and 2014. Note that some pictures included more than one reference to a device and so (1) the number of references to a device could exceed the number of pictures analysed and (2) the percentages shown are not strictly

the percentage of pictures with references to the device, but they are indicative of the prevalence of the device.

Almost all the pictures included references to cellphones and some included more than one reference. In 2013, all but 9 of the cellphones depicted were recognizable brands and models of smartphones and in 2014, all but 5. While some of these may represent student's aspirations, it seems clear that most students have smartphones and view them as a central technology in their information-related activities. (In the table below, only smartphones are counted as computing devices; cellphones that could not be identified as smartphones have been omitted.)

Laptop computers are more prevalent than desktop computers in students' information systems, with the prevalence of desktop computers declining between 2013 and 2014. Tablet devices, on the other hand, were more prevalent in the pictures from the class of 2014 than they had been in 2013. In 2014, three students made references to wearable computing devices, one to Google Glass and two to smart watches.

Although there are many references in the student pictures to cloud storage, a large number make use of external storage devices such as external drives, USB drives and memory cards to store information. This may well be a reflection of some challenges in connecting to remote storage services including reliable access and cost.

Table 1: References to technology devices in students' personal information systems

Device	2013 n=325	2013 %	2014 n=456	2014 %
Smartphone	324	100%	445	98%
Laptop computer	247	76%	355	78%
External storage drive	106	33%	273	60%
Desktop computer	113	35%	134	29%
Tablet device	94	29%	162	36%
Wearables	0	0%	3	1%
Portable music device	88	27%	75	16%
Television	58	18%	18	4%
Radio	29	9%	12	3%
Digital camera	55	17%	7	2%
Ebook reader	13	4%	21	5%
Gaming console	17	5%	21	5%
Printer	8	2%	5	1%
Scanner	4	1%	2	0%
Fax machine	0	0%	2	0%

The convergence of devices can be seen in the decline from 2013 to 2014 in the number of references to devices such as television sets, radios, digital cameras and music players. Because students still made references to radio and television programmes and music web sites in 2014, we can assume that they are using their other computing devices to access this content.

The prevalence of ebook readers and gaming consoles in students' personal information systems did not change much between 2013 and 2014. This may reflect a reasonably constant proportion of students with interests in reading and gaming respectively. However, the prevalence of these devices does not necessarily reflect the full extent of the use of ebooks or gaming since students may also access ebooks and games from their computers or tablets. Students also made references to ebook applications and gaming applications, which data has not yet been analysed.

Students' information systems are largely paperless, with printers, scanners and fax machines playing an insignificant role.

8. WHAT SOURCES OF INFORMATION DO STUDENTS USE?

All items in the students' pictures that could be considered information sources were identified and then similar types of information sources were clustered together, based on the characteristics of the source and the type of information. Table 2 shows the types of information sources identified. The indented rows show the most frequently depicted information sources within each type.

Table 2: Types of information sources in students' personal information systems

Nature of source	2013 (n=325)	%	2014 (n=456)	%
Generic information sources				
Social networks	1045	322%	1538	337%
WhatsApp	*242*	*74%*	*380*	*83%*
Facebook	*280*	*86%*	*369*	*81%*
Twitter	*201*	*62%*	*281*	*62%*
Other generic sources	399	123%	465	102%
Internet	*53*	*16%*	*181*	*40%*
YouTube	*159*	*49%*	*137*	*30%*
Google	*149*	*46%*	*73*	*16%*
People (not academic)	250	77%	323	71%
Friends	*132*	*41%*	*203*	*45%*
Family	*53*	*16%*	*62*	*14%*
Academic information sources				
All academic sources	294	90%	252	55%
LMS	*98*	*30%*	*149*	*33%*
Books	*74*	*23%*	*75*	*16%*
Sources of specific information				
Retail information	93	29%	207	45%
Leisure and cultural	160	49%	99	22%
News media	164	50%	85	19%
Transport and travel	21	6%	52	11%
Weather	16	5%	7	2%
Business and investing	9	3%	5	1%

Some information sources were clearly associated with specific types of information, for example the web site of a retail organisation would provide information about their products and a weather service would provide information about the weather. However a large number of information sources were generic in that it was not possible to discern what kinds of information might be provided from that source. Generic information sources were analysed in three categories, social media, people (not associated with academic roles) and other generic sources.

Social media dominates students' personal information systems and it is clear that students consider social media their most important source of information. All pictures included one or more references to social media, with an average of three distinct social media for each student. The social media applications that dominate are WhatsApp, Facebook and Twitter.

People (other than those that students encounter in their academic pursuits) included friends, family and depictions of unspecified people. Students no doubt use social media applications to communicate with people in this category and we debated whether to analyse people and social media together. However, social media puts students in touch with a far wider range of people (as is evident in the more frequent references to social media), so these types of information sources seemed to warrant separate discussion.

Other generic information sources referenced included the Internet and search engines such as Google used to access the World Wide Web, as well as information sites such as YouTube and Wikipedia.

Several information sources are clearly associated with academic activities; the most frequently depicted being the university's learning management system. Books, ebooks, textbooks and reference books such as dictionaries were the second most often mentioned academic resource, although few students included the library (9 in 2013 and 4 in 2014). Few students depicted lectures as a source of information (16 in 2013 and 9 in 2014) and even fewer included academic staff in their pictures (2 in 2013 and none in 2014). Other people that students encounter in the academic context, including classmates and project teammates, were represented and we identified them as sources of academic information. Educational web sites such as Khan Academy, Mindset Learn and Master Maths were also mentioned by students, although infrequently.

Specific information sources reveal categories of information that students seek. Retail information sources were frequently depicted in the students' pictures, showing that information for making buying decisions is important to them. Less important is information about leisure and cultural pursuits including music, movies and series, events, sports, games, dining out and religious activities. Traditional news media featured as information sources, including television, radio, magazines and newspapers, although several of these are consumed in electronic form. Students access information relating to their travel and transport including applications for bus and train timetables (in 2014 but not in 2013), navigation tools and web sites and applications providing traffic information. A few students seek information about the weather and access web sites relating to business and investing.

In answer to our third research question, the sources of information provided by the university are depicted in students' personal information systems less often than other generic and specific information sources. Given that students compiling these personal information systems were two weeks into their first year of university at the time, it is perhaps not surprising that social and generic sources of information dominate. At this point they are likely to be beginning to apply their minds to the sources of information that relate to their academic work.

9. AN ECOLOGICAL MODEL OF STUDENTS' INFORMATION SEEKING BEHAVIOUR

Williamson [20] made the point that information seeking and use is highly contextual and that contextual constraints frame these behaviours. In her study of the information behaviour of older people, she identified biological, social, economic and physical circumstances as providing these contextual constraints. Prior research into student success at the University of the Witwatersrand identified three sets of conditions that impact on student success; firstly the student's biography, which includes their socio-economic, cultural and linguistic background; secondly, the learning environment created by the institution; and thirdly the student's agency or the extent to which the student can negotiate the teaching and learning processes [6]. Thus we propose using these elements as the contextual constraints for an ecological model of student information seeking behaviour based on Williamson's model [20] (the outermost layer of Figure 2).

In the inner layers of the model we depict the three different student information sources that we identified from the data as concentric bands, where the size of each band reflects the frequency of use of each source. How the use of these sources is mediated by the contextual constraints is discussed here, based on literature.

Students' socio-economic, educational and linguistic backgrounds influence the technologies that they have access to and experience of, and so constrains the configuration of their personal information systems. By making explicit the construction of a personal information system and exposing students to a range of devices and applications that are available, they are encouraged to develop a richer set of information behaviours that they can draw on in their studies.

Although students at the University of the Witwatersrand make extensive use of digital and online resources, studies of student information behaviour in other African universities [2], [15] show that students depend on physical resources when electronic resources are not available or difficult to access. Thus the information services provided by the university are an important contextual influence on students' information behaviour.

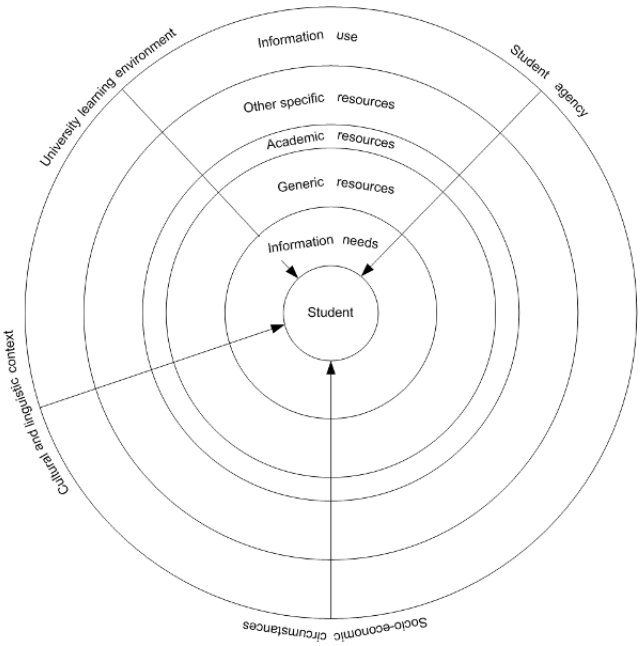

Figure 2: Ecological model of student information seeking and use (Adapted from Williamson, 2005)

Research has shown that all students newly arrived at university are disadvantaged by their lack of understanding of the academic discourse and expectations [11] and that some lack specific skills or the self-efficacy needed to succeed [6]. Students need to develop sophisticated and highly individual personal information systems that can deal effectively with degrees of visibility of information, task urgency and workflows [13]. Each student's ability to do this effectively depends on their skills, access to technologies and creativity, as well as prior exposure to effective information management.

In particular, adjusting to the university environment requires accessing information about the university discourse that students do not know that they lack. A rich information system that caters for both goal-directed information seeking (used, for example, to find information to complete an assignment) and incidental information acquisition (used, for example, to understand

expected ways of behaviour), can assist students in acquiring the knowledge and skills that are critical to successful navigation of university studies [6], [11], particularly the knowledge that they do not yet know that they need. Incidental information acquisition also has the benefit of resulting in positive feelings that boost a student's sense of agency [8].

Williamson's model distinguished between goal-directed information seeking and incidental information acquisition. The data that we have does not enable us to make this distinction, but goal-directed information seeking is likely to make use of academic and specific sources, while prior studies suggest that students will find incidental information from social media and other generic sources [8]. These generic information sources may thus be important for students in developing their understanding of the expectations of the academic environment needed to succeed at university [6], [11].

10. CONCLUSIONS

Students' information behaviour can be understood in terms of an ecological model that maps the information sources they use and the contexts that influence their success in accessing information. University students have to develop a complex personal information system and master a range of information behaviours.

Students access a wide range of generic information sources, with social media applications dominating their information behaviour. These generic sources of information have the potential to support students' incidental information acquisition, which is important in addressing their common lack of knowledge about academic discourses and expectations on entering university.

For students, the learning management system is the most important academic information source, with traditional academic activities of lectures playing a small role in their information gathering. In particular, members of the academic staff are not seen as significant sources of information for students. This observation supports moves towards blended learning and away from traditional modes of instruction. The role of academic staff may well need to shift from being presenters of academic information towards being choreographers of learning materials delivered through other media.

Most undergraduate students use smartphones and laptop computers, with desktop and tablet computers as an alternative. Although students use cloud storage options, they mostly make use of physical storage devices that do not depend on access to networks. This suggests that it might be worth the institution providing smartphones to the few who do not have them in order to (1) facilitate access to information sources that will provide much-needed incidental information and (2) facilitate teaching and learning activities designed to take advantage of the capabilities of smartphones. The provision of reliable, free, wireless network access should also be a priority for institutions.

This paper has examined students' information sources and the technology devices they use to access them. Further research is needed to better understand the types of information that are being accessed through generic information sources and students' uses of academic information sources, as well as more in-depth evidence of how context impacts information behaviour. In 2015 we have expanded the assignment from which this data was collected to include additional elements which will facilitate such further investigations.

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Evaluating Mobile Centric Readiness of Students: A Case of Computer Science Students in Open-Distance Learning

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ABSTRACT
This study examined the mobile centric readiness of Computer Science students at an Open and Distance Learning (ODL) university in South Africa. Quantitative data was captured through a survey and a total of 129 students responded to the survey. The mobile centric readiness of students was evaluated based on factors that could affect the readiness of students in accessing and interacting with mobile centric services. The factors were Infrastructure ownership, Knowledge of device functionality, Sources of internet access, Mobile phone internet activities and Context of use. The results of this study confirmed that the students satisfied the readiness factors and they are ready to use mobile phones as tools for information access and interaction in learning.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: Distance learning

Keywords
Mobile centric services, mobile information access, mobile readiness

1. INTRODUCTION
As the mobile phone market matures in terms of penetration rate, subscription rate, handsets functionality and mobile centric services, it is evident that mobile phones are now part and parcel of many people's daily lives. Statistical reports estimated that the number of global mobile phone subscriptions would have reached 7 billion by the end of 2014 [16]. Globally, this reflects a ratio of one mobile phone per person. High mobile phone penetration has made it possible for digitally alienated communities in developing countries to have improved access to business, health, education and social services. Indeed, this has truly transformed the lives of many people in developing countries. However, the benefits of mobile phone penetration have not been homogeneous across the spectrum of people's lives, in particular, in education relative to business and social life. Even though mobile phones are presumed to be appropriate information access and interaction tools in teaching and learning [15, 26, 27], their uptake has not been fully realized. The slow growth has recently been identified as a cause of concern as it could derail the opportunities presented by mobile phones as tools for inclusive information access and interaction in learning [4, 15]. Several factors have been identified as restraining full adoption of mobile centric services in education and they include technological factors, economic factors and human factors. This study focused on the human factors as a source of slow growth in the adoption of mobile centric services in teaching and learning. Among all the stakeholders who could be implicated in the adoption of mobile centric services in teaching and learning, this study focused on the readiness of students as critical adopters of the technology. Hence, the objective of this study is to examine the readiness of students at a Higher Educational Institutions (HEI) for accessing and interacting with mobile centric services in teaching and learning. The objective translated into the following research question, "How ready are the students in accessing and interacting with mobile centric services at the university?"

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2. Readiness
Higher educational institutions in developing countries could benefit from mobile phone information access and interaction technologies effectively if the students are ready to use the technologies. The readiness of students in using ICT related technologies such as mobile cellular phones is known as e-readiness [23]. The term E-readiness has received numerous definitions. Sachs [23] defined e-readiness as, "the degree to which a community is prepared to participate in the Networked World. It is gauged by assessing a community's relative advancement in the areas that are most critical for ICT adoption and the most important applications of ICTs." Maugis *et al.* [20] defined e-readiness as, "the ability to pursue value creation opportunities facilitated by the use of the Internet". E-readiness has also been defined as, "the extent to which a market is conducive to Internet based opportunities, taking into consideration the quality of IT infrastructure, government initiatives, and the degree to which the internet is creating commercial efficiencies [12]." The definitions of e-readiness revolve around the preparedness of people in using ICTs to pursue value creation opportunities in their daily lives. Hence, students at HEIs in developing countries need to be ready to exploit the opportunities presented by mobile phones as information access and interaction tools in teaching and learning. The following section reviews frameworks for e-readiness as way of understanding the concept.

2.1 Frameworks for evaluating readiness
This section reviews four e-readiness frameworks/models and they are an *Eclectic model for assessing e-learning readiness in the Iranian universities* [9], *Readiness combination model for acceptance of e-learning* [3], the *Nilson and Carlos Machado Model* [19], and the *Haney model* [14]. The frameworks were designed for evaluating the readiness of institutions in implementing e-learning. The consensus among the models for

evaluating e-readiness is that when introducing e-learning at an institution, all the stakeholders that would be involved in the project have to be assessed for e-readiness [3, 9, 14, 19]. The stakeholders include administrative managers, academics, and students. Common dimensions among all the proposed models for evaluating e-readiness were technological infrastructure, finance, human resources and course content [3, 9, 14, 19].

The frameworks do not directly inform on the readiness of students in using mobile centric services in teaching and learning but they have some common dimensions that are important to this study. The dimensions could be summarized as follows:

- *Technological infrastructure readiness* assessment focuses on evaluating if existing infrastructure could sustain the new intervention. If the existing infrastructure cannot provide or sustain the services of a new intervention, the institution would be expected to provide the required infrastructure. This dimension is important in this study because students would only use mobile phones as information access and interaction tools if they own or have access to the devices.
- *Human resources readiness* focuses on evaluating the incumbents in terms of motivations, attitudes, resistance and skills required in providing e-learning. With respect to human resources readiness, Machado [19] recommended that prior to the implementation of e-learning services, it is important to understand the administrators' vision, their abilities in implementing policies and strategies that inform e-learning. The policies and strategies would be expected to capacitate other stakeholders in terms of motivation and training.

The *Readiness combination model for acceptance of e-learning* [3] had a unique dimension not included on other models, which is the business dimension. The business readiness of an institution could be measured by assessing its goals, needs, motivators, resources and constraints with respect to e-learning. Two of the models, the *Eclectic model for assessing e-learning readiness in the Iranian universities* [9] and the *Readiness combination model for acceptance of e-learning* [3] suggested that the e-readiness evaluation could be based on the culture of the institution. Institutional culture could be evaluated in terms of its response to technology adoption, staff training, budget, provision of resources and management support.

The cultural aspect is important in this study because it is essential to understand the mobile centric culture of students in evaluating their readiness. The mobile centric culture of students is engraved in the Generation –Y [21] culture. The Generation-Y people have been described as people born with technology [22], have a high aptitude for technology use, propensity for establishing social networking groups [18, 25], appreciate device portability and quickly turn to internet for information access [25].

The technological culture and infrastructure ownership of students are the basis of mobile centric readiness evaluation in this study. Hence, the mobile centric readiness of students in this study was evaluated based on ICT infrastructure ownership, Knowledge mobile phone functionality, Sources of Internet access, Mobile phone internet activities and Context of use.

3. Research Methodology

This study evaluated the readiness of Computer Science students at an ODL university in South Africa. This was achieved by employing a quantitative survey to collect data from students. The design of the questionnaire was informed by the findings of the literature review analysis, and findings from the previous exploratory qualitative surveys conducted in another study targeted at a different group of students [6]. The questionnaire had 10 closed ended questions, structured as multiple choice questions and Likert scale rating. The questionnaire measured the readiness of students based on students' ICT infrastructure ownership, Knowledge of mobile phone functionality, Sources of internet access, Mobile phone internet activities and Context of use. The questionnaire was distributed electronically to students using Google forms. The students were invited to respond to the survey questions through emails.

3.1 Participants

This study employed purposeful sampling to select the survey respondents. Purposeful sampling was explained as [7] "the researcher intentionally select participants who have experienced the central phenomenon under study" The students who have experienced the phenomena under study are University of South Africa students. The university has a student population of over 250,000 students spread across six colleges. Due to large student population, it was too expensive and time consuming to collect data from all the students, hence this study employed purposeful sampling to collect data.

A total of 129 participants completed the questionnaire. The participants were third year students registered for a database course in the School of Computing at the university. The gender ratios of the students were 32% female and 68% male.

3.2 Data analysis

After collecting data from the survey, data was cleaned in preparation for analysis. Data cleaning involved verifying that each question had a valid response. The questionnaire captured both nominal and ordinal data. Descriptive statistics was employed to analyze both the nominal and ordinal data in order to give a summary of how the group responded to each of the survey questions. Factor analysis was employed to uncover trends that were not visible from descriptive analysis.

4. Results

The results focus on the mobile centric readiness of students in terms of ICT infrastructure ownership, Knowledge of mobile phone functionality, Sources of internet access, Mobile phone internet activities, and Context of use.

4.1 ICT infrastructure ownership

The questionnaire included a question that measured the infrastructure owned by the students. Determining the ICT infrastructure ownership helped in comparing mobile phone ownership against other devices owned by the students. The participants were asked a multiple choice question that required them to choose the ICT devices that they own from a list by a "*yes*" or a '*no"*. The question reads, "*Which of the following electronic communication devices do you own?"*

The results of data analysis are presented in Table 1. The results established that all the students (100%) owned a mobile phone. The second ranked device owned by the students was a laptop (81%), followed by a printer (54%), a desktop computer (53%) lastly an iPad/Tablet (53%).

Table 1: Infrastructure ownership

Which of the following electronic communication devices do you own?	Yes
Desktop computer	53.1%
Laptop computer	81.3%
Printer	53.9%
iPad/tablet	18.8%
Mobile phone	100.0%

The results show that all the students owned a mobile phone irrespective of gender, age and funding of the studies. One of the measures of readiness [3] is infrastructure ownership, hence the results confirm that the students are ready to use mobile phones as information access and interaction tools.

4.2 Knowledge of mobile phone functionality

The questionnaire included two questions that evaluated students' knowledge of their mobile phone brands and functionality. The first question asked students to identify their mobile phone brands, *"What is the brand of your mobile cellular phone?"* The second question asked students to choose from a list of features with a *"yes", "no" or "I do not know"* to confirm if the feature is available on their phones. The question reads, *"Which of the following features are available on your mobile phone?"*

The data analysis results revealed that all the students identified the brands of their mobile phones. Figure 1 show that the popular mobile phone brands were Blackberry (33%), Samsung (29%) and Nokia (21%).

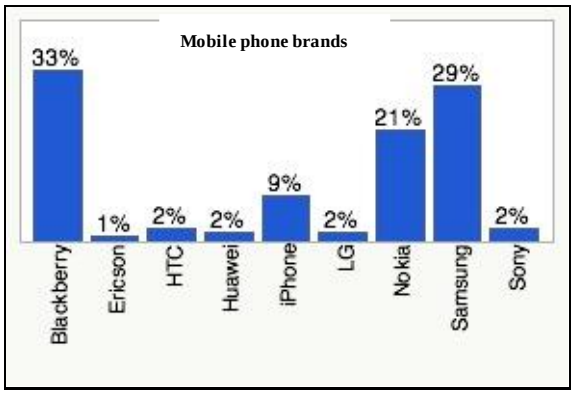

Figure 1: Mobile phone brands distribution graph

With respect to identifying mobile phone features, the descriptive statistical results are presented in Table 2. The table shows that the students identified features on their mobile phones as Internet access (97%), email (97%), camera (97%), video player (97%), apps download (87%) voice recorder (92%) and document reader (82%). It is important to note that all the students identified that their mobile phones had SMS, calendar and a clock. There were some features that other students failed to identify if they were available on their mobile phones, for example apps download (8%), voice recorder (3%), or document reader (9%). It was notable that some students' mobile phones had no internet access (3%), emails (2%), camera (3%), video player (3%), apps download (5%), voice recorder (5%) or document reader (9%).

Table 2: Mobile phone features

Which of the following features are available on your mobile phone?	Do not know	No	Yes
SMS	0.0%	0.0%	100.0%
Internet access	0.0%	3.1%	96.9%
Camera	0.0%	3.1%	96.9%
Video player	0.0%	3.1%	96.9%
Calendar	0.0%	0.0%	100.0%
Emails	0.8%	2.3%	96.9%
MP3 player	2.3%	3.1%	94.6%
Voice recorder	3.1%	4.7%	92.2%
Games	0.0%	3.9%	96.1%
Document reader	8.5%	9.3%	82.2%
Twitter	7.0%	10.9%	82.2%
Clock	0.0%	0.0%	100.0%
Maps	8.5%	9.3%	82.2%
Instant Messenger	11.6%	6.2%	82.2%
Apps download	7.8%	5.4%	86.8%

The results revealed that even though most students managed to identify most features on their mobile phones, a few students did not know if their phones had certain features or not. The readiness of students in using their mobile phones could be affected by the absence of some features. There are some students who indicated that their mobile phones do not have features such as Apps download or Internet.

4.3 Sources of Internet access

The questionnaire included a question that asked students to reveal their sources of Internet access. The question reads, *"Where do you access the Internet and how often do you do this per week?"* The question was based on a Likert scale rating and explored where the student access the Internet and their frequency of access. Understanding the sources of internet access helped in comparing mobile phone access readiness with other sources of internet access.

The data analysis results are presented in Table 3. The results established that 72.1% of the students had accessed internet from a computer at home more than four times per week and 9.3% had never accessed internet from a computer at home. It was noted that few students had accessed internet from Internet cafes or someone else's house. The results indicated that 4.7% of the students had accessed internet from the Internet cafes more than four times a week and 83.7% had never done that. With regards to accessing internet from someone else's house, 1.6% of the students had done that more than four times a week and 97.7% had never done that.

It was noted that students mostly access internet from their work place and mobile phones. The descriptive results in Table 3 show that 62% of the students had accessed internet at their workplaces more than four times a week and 31% of the students had never done that. Notably, 78.3% of the students had accessed internet from their mobile phones more than four times a week but 7.8% had never done that.

Table 3: Sources of internet access

"Where do you access the Internet and how often do you do this per week?"	Never	Once	Twice	Three times	More than four times
Computer at home	9.3%	5.4%	7.8%	5.4%	72.1%
Internet cafe	83.7%	7.0%	3.9%	0.8%	4.7%
Someone else's house	97.7%	0.0%	0.0%	0.8%	1.6%
Work place	31.0%	2.3%	1.6%	3.1%	62.0%
Mobile cellular phone	7.8%	7.8%	4.7%	1.6%	78.3%

The data analysis results revealed that a mobile phone is a device through which majority of students access internet. It was established that a significant number of students had accessed internet at their work places. It was noted that there were some students who had accessed internet from internet cafes and other people's houses.

4.4 Mobile phone internet activities

The questionnaire included a question that asked students to reveal internet activities that they usually do on their mobile phones. The question reads, "*As part of your normal routine, to what extent do you engage in the following activities on your mobile phone?"* The question was based on a Likert scale rating and required students to indicate the frequency at which they do an activity.

The data analysis results are presented in Table 4. The activities that the students often and very often engage with through their mobile phones included checking email (83%), replying emails (73%), viewing pictures received on a mobile phone (75%), taking pictures (76%), chatting with friends (74%) and searching internet for news (68%). Notably, there were some activities which some of the students had never done on their mobile phones. The activities included downloading videos (37%), downloading songs (32%), watching online videos (24%), searching for movies or films (32%) and surfing the web for leisure (26%).

Inspecting Table 4 shows that there were certain activities that the students tended to perform more often than others. Further investigation using Factor analysis was undertaken to see if there were some latent variables within the dataset. The following section presents the categories of the general mobile phone internet activities found from Factor analysis.

Table 4: General mobile phone activities

"*As part of your normal routine, to what extent do you engage in the following activities on your mobile phone?"*	N/A	Never	Seldom	Often	Very Often
Search internet for news	4%	8%	20%	22%	46%
Search internet for facts	6%	19%	25%	19%	31%
Search internet for health information	5%	15%	29%	25%	26%
Access sport results	6%	20%	26%	21%	26%
Search for movies or films	5%	32%	37%	12%	13%
Watch a video online	4%	24%	40%	14%	17%
Download videos	5%	37%	26%	16%	16%
Access and update social networking sites	4%	8%	21%	27%	40%
Check emails	4%	2%	12%	19%	64%
Reply emails	4%	3%	19%	19%	54%
View pictures on a mobile phone	4%	5%	16%	37%	38%
Download songs	4%	32%	32%	12%	19%
Take pictures	4%	5%	15%	31%	45%
Download documents	4%	16%	22%	23%	35%
Surf web	5%	26%	25%	21%	22%
Chat with your friends	3%	9%	13%	24%	50%

4.4.1 Categories of general mobile phone internet activities

The results of Factor analysis are presented in Table 5. The factors were determined based on the Eigenvalues, Cumulative percentage of variance, and the Scree plots. The Factor analysis extraction methods used was the Maximum Likelihood and the rotation method was Varimax. An initial analysis to get the eigenvalues for each factor extracted 3 factors with Kaiser's criterion of greater or equal to 1. The percentage variance for each factor was also recorded. The 3 factors had eigenvalues of 7.3205 (45.753%), 1.4975 (9.359%) and 1.0974 (6.842%). The 3 factors contributed a total variance of 61.95%. The 3 factors were returned for analyzing the data and the items with factor loading greater than 0.4 were considered to be valid. Table 5 shows the results after rotation.

Table 5: Rotated factor loadings of mobile phone activities

Item	Factor 1 *(Information gathering activities)*	Factor 2 *Communication activities)*	Factor 3 *(Social connection activities)*
1. Search internet for news	**0.59**	0.42	0.23
2. Search internet for facts	**0.56**	0.19	0.15
3. Search internet for health information	**0.59**	0.34	0.25
4. Access sports results	**0.50**	0.27	0.22
5. Search for movies or films	**0.60**	0.17	0.04
6. Watch a video online	**0.65**	0.09	0.34
7. Download videos	**0.75**	0.13	0.12
8. Access and update social networking sites	0.26	0.31	**0.46**
9. Check emails	0.23	**0.84**	0.25
10. Reply emails	0.28	**0.81**	0.24
11. View pictures on a mobile phone	0.26	0.30	**0.66**
12. Download songs	**0.70**	0.19	0.23
13. Take pictures	0.12	0.09	**0.78**
14. Download documents	0.53	**0.52**	0.24
15. Surf the web	**0.55**	0.26	0.34
16. Chat with your friends	0.25	0.38	**0.45**
Eigenvalues	7.321	1.498	1.097
% Variance	45.75%	9.35%	6.84%
Cronbach Alpha	0.90	0.90	0.84

The factors that group under Factor 1 represented *Information gathering activities*. Factors that group under Factor 2 represented *Communication activities*. The factors that group under Factor 3 represented *Social connection activities*.

There were some overlaps on Item 1 (*Search internet for news or information on current events*) between Factor 1 and Factor 2, and Item 14 (*Download documents*) as shown in Table 5. In such circumstances, the items were classified based on either the highest score or on contextual perspectives. For example, Item 1 was classified under a factor with the highest score. On the other hand, item 14 was classified on contextual perspective.

Reliability analysis was applied to each of the factors identified during Factor analysis. The results show that all the factors were reliable, with high scores of Cronbach Alpha coefficients above 0.7. The values of the Cronbach Alpha coefficients were: α = 0.90 for Factor 1 (*Information gathering activities*), α = 0.9036 for Factor 2 (*Communication activities*) and α = 0.8434 for Factor 3 (*Social connection activities*). The coefficient value of item 9.4 (0.9006) was above the overall reliability coefficient value by a margin of 0.006 and could have been deleted. Since the overall value of the coefficient of α is high, deleting the value would make a minimal contribution in improving the value of α.

4.5 Context of use

The questionnaire included a question that explored the context in which the students use their mobile phones. The question required the students to agree with a *"yes" or a "no"* on statements that described their mobile phone use. The question was, *"Please select from the statements below those that best describe your mobile phone use in the given context?*"

The data analysis results established that majority of the students agreed that they always carry their mobile phones (96%), they use their mobile phones when travelling (93%), they use their mobile phones to capture situated interesting events (84%), they use their mobile phones when doing other things and they use their mobile phones at bus or train stations as depicted in Figure 2.

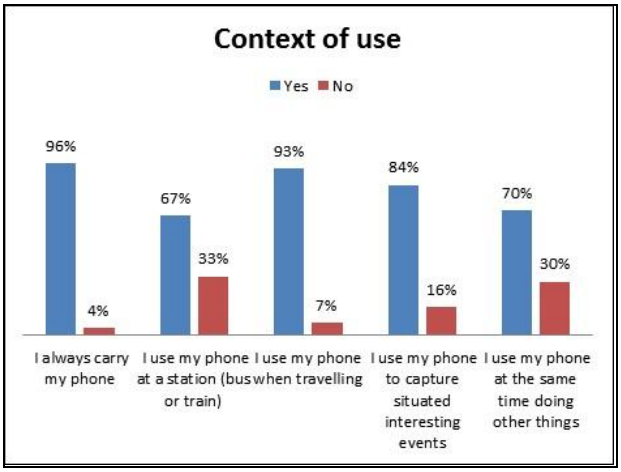

Figure 2: Context of use

The responses to this question indicate that the students always carry their mobile phones and they use them to accomplish a variety of tasks in different context. Additionally, the results confirm the notion that mobile phones helps with removing communication and interaction barriers.

5. Discussion

This section discusses the findings of the research question, *"How ready are the students in accessing and interacting with mobile centric services at the university?"* The discussion focuses on the mobile centric readiness of students in terms of ICT infrastructure ownership, Knowledge of mobile phone devices, Sources of internet access, Mobile phone internet activities and Context of use.

5.1 ICT infrastructure ownership

Infrastructure ownership is one of the factors that determine if a group of people is ready to use a technology [9, 19]. The results of this study established that mobile phones were the only IT devices owned by all the students if compared to other devices. Hence, students seemed to be ready to use mobile phones as information access and interaction tools because they already own the devices regardless of their gender and age. Comparing the ownership of

mobile phones (100%) with iPad/Tablets computers (20%), it is important to note that few students owned iPad/Tablet computers. Therefore, mobile phones are accessible to most students and present a readily available channel for information access and interaction in teaching and learning. This dispels the uncertainty that the provision of mobile phone services may introduce an information access and interaction divide [1, 2]. In the end, the results showed that all the students own a mobile phone and this presents an opportunity for providing students with mobile centric services at the university.

5.2 Knowledge of mobile phone functionality

All the students identified brands of their mobile phones and popular brands were Blackberry, Samsung and Nokia. With regard to the mobile phone features, majority of the students managed to identify most of the features on their mobile phones. All the students identified features such as SMS, Clock and Calendar. Even though most of the students identified most features on their mobile phones, a few students failed to do so. Some students could not identify whether their mobile phones had features such as a voice recorder, Twitter, Skype, Apps download, Instant messenger, or Maps. The findings of this study support the study which found that many people with mobile phones would not know if their mobile phones had internet or not [10]. Therefore, students who were not aware of all the features of their mobile phones were not fully ready to use their mobile phones.

The implications of the findings are that it would be problematic for an HEI to implement mobile information access and interaction services simply on the assumption that students have mobile phones. An institution should assess the types of mobile phones that the student population possesses and decide on an implementation strategy based on that. The mobile phone services that an institution provides are expected to be accessible by mobile phones with the least of the features. If some students are not knowledgeable about the features of their mobile phones, the institution would be expected to provide training on that aspect.

5.3 Sources of internet access

The results of data analysis revealed that students mostly access the internet from a mobile phone (78.3%), followed by a computer at home (72.15%) and at their work place (62%). The results showed that internet access on a mobile phone dominated internet access compared to other platforms. This reflects the readiness of students in utilizing mobile phones as internet access tools. The margins between mobile phone access (78.3%) and computer at home access (72.05%) were 6.15% and between mobile phone (78.3%) and work place (62%) was 16.3%. The margins are small and may suggest that even though mobile phones dominate internet access, the students also depend on computer access especially when they are at their homes or at their work places. This finding is in line with a study which found that even though students use their mobile phones to access the internet they often visit public internet access venues [11].

Inversely, the results established that some students have never accessed the internet from a mobile phone (7.8%), computer at home (9.3%) and computer at work place (31%). The results revealed that few students access the internet from Internet cafes (4.7%) or from other people's houses (1.6%). Presumably, the reason for accessing internet from Internet cafés or from other people's houses is that the students do not have access at their home. If such students have mobile phones with internet access, they would mostly access internet from a mobile phone.

5.4 Mobile phone internet activities

This study evaluated students' mobile phone internet activities as a way for measuring their mobile centric readiness. The data analysis results revealed that the students seemed to be ready to use their mobile phones as tools for information access and interaction. The Factor analysis results established that students' mobile phone internet activities clustered around three categories of activities, which are *Information gathering activities*, *Communication activities*, and *Social connection activities*. The discussion in the following sections focuses on each of these categories.

5.4.1 Information gathering activities

The information gathering activities that the students were familiar with included reading online news, searching the internet for facts to support an argument, searching for medical information, accessing sports results, searching for movies, just to mention a few. Information gathering was described as a situation where someone visits a web to purposively research on some topic or to collect data [24]. This study considers information gathering as a characteristic of students' readiness in using mobile phones as an information access and interaction tool. The results confirms that the students are mobile centric and mobile phones are an integral part of their daily lives [5, 11, 13, 28]. This suggests that if the university provides students with mobile phone services that enable them to gather information, the students should be ready to use the services.

5.4.2 Communication activities

The communication activities that the students were familiar with included SMS texting, telephone calling, instant messenger chatting, checking email, replying to email and downloading email documents. Earlier studies on information access and interaction [8, 17] identified communication as one of the reasons for accessing the internet. In this respect, the results of this study reflect that the students have some mobile phone communication experience, which implies that they could be ready to communicate with the university through mobile phones.

5.4.3 Social connection activities

The social connection activities that the students were familiar with included visiting social networking sites, chatting with friends, uploading and viewing pictures. The experiences gained when interacting on social media platforms is important in that it improves students' communication and interaction, sharing of content and knowledge, collaboration and virtual presence. Additionally, technologies that are available on social media platforms could enable students to have synchronous peer mentoring and group work. Therefore, the findings of this study have shown that the students are ready to use their mobile phones for information access, interaction and sharing resources.

5.5 Context of use

The data analysis results showed that most students always carry their mobile phones and use them at any given time and at anywhere. The user context findings imply that if the students always carry their mobile phones, the university can provide students with mobile phone content and services, which they can access from anywhere. The students also indicated that they use their mobile phones when they are in public environments such as bus or train stations, and when they are travelling. If the students use their mobile phone to access and interact with information in any context, the assumption is that the students are ready to access and interact with university's information systems in any context.

6. Limitations of the study

The students were all from the School of Computing at an ODL university in South Africa. The technological aptitude of Computer Science students could be different from other students in different faculties at the university and could have influenced the presumed mobile centric readiness. Furthermore, ODL students may have a different mobile phone usage culture. Hence, more research is needed to generalize the findings. The study could be extended to the whole university or other universities, creating room for evaluating the mobile centric readiness of students in the context of developing countries.

7. Conclusion

This paper discussed the evaluation of mobile centric readiness of Computer Science students at an ODL university in South Africa. The results of data analysis established that the students have the required characteristics for being mobile centric. The characteristics were confirmed by the fact that all the students own a mobile phone. Notably, Tablet-PC's were much less common (only 18.8%). The results also confirmed that students have knowledge of the features of their mobile phones, they use their phones to accomplish a variety of activities and they interact with the mobile phones in different contexts. However, there were some students who did not use (or know how to use) all the features and since those could be critical features which the institution would have to make provision for support. The mobile phone factors identified could be useful in planning and managing the university's mobile use strategy since it allows prioritization of mobile phone usage activities. Therefore, this study informs the university on how they should approach the provision of mobile centric services to ensure that students do not resist the services

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Strengthening the Teaching-Research Nexus in a Large First Year Information Systems Class.

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ABSTRACT
This case study reviews a project of strengthening the teaching-research nexus in the undergraduate curriculum in a large class (416) of first year students at a South African University. The aim of the project was to introduce students to researching a topical area that is relevant to their lives, that is in the existing curriculum, and to develop skills of collaborative work. This was done by designing an assignment that required students to access information, use cloud collaborative productivity tools (Google Docs), conduct interviews, writing summaries and synthesis, as well as reflecting on what they have learnt by posting on a public forum (Facebook). In order to manage the scope of the assignments and the logistics involved, the research director, lecturer, class tutors, undergraduate writing centre director, as well as the faculty librarian were involved. Some of the challenges of such a project are adequate funding and support from the department, as well as lecturers concerned, as well as making provision for a dedicated research director and tutor system to coordinate, manage and administer such assignments.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: Computer Uses in Education – collaborative learning, computer-assisted

General Terms
Management, Design, Human Factors, Languages, Theory.

Keywords
Teaching-research nexus, undergraduate curriculum, social networking, education, tutors, Google Docs, Facebook.

1. INTRODUCTION
Preparing students for a complex, challenging and uncertain future that requires them to solve unforeseen problems, cannot be catered for by delivering discrete bodies of knowledge for memorization and repetition, but requires the development of faculties of critical inquiry [1].

> *"Students are going to need to be able to critically evaluate knowledge; to make rational judgments in the light of good evidence, evidence that they perhaps gather, and to reflect on what they are doing and why"* [1, p. 141].

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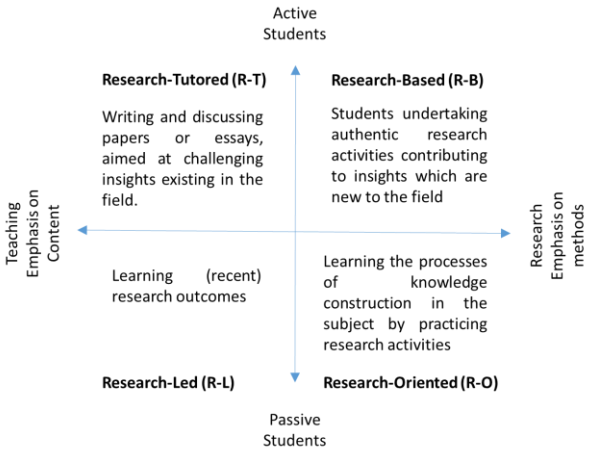
This cannot be achieved merely by improved teaching practices, but require students to become active participants in finding, evaluating and constructing such new knowledge. This requires a greater focus on students participating in constructing the content and material of the curriculum as opposed to being passive recipients of this information. By establishing a greater link between teaching and research [1] educators can give students just this opportunity to make sense of this wealth of information. In addition, students are actively involved in the research, and develop practical skills such as finding and analysing information, interviewing people, writing research reports etc. that are of benefit both to their later careers and to their postgraduate studies, as well as more actively engaging them [2]. The aim of this project was to introduce a research component in the undergraduate curriculum (1st year) in order to expose first-year students to research techniques as well as providing them with hands-on experience of using modern cloud computing (Google docs) and social networking applications (Facebook). This stands in contrast to the traditional approach of merely teaching students about these concepts and applications from the textbook. It was also intended to evaluate the student's learning in a different way to the traditional multiple-choice questions or memorize and test approach. Lastly, it was hoped to learn about the challenges of introducing a new way of learning to large classes in a South African context where access to computers in the classroom are limited.

2. THE TEACHING-RESEARCH NEXUS
As a lecturer in a higher education institution, one is by nature involved in teaching and conducting research. The difficulties in explicating the linkage between teaching and research is as a result of the differences in which these terms are conceptualized [3]. The reason why a nexus exists at all, is due to the separate development (fragmentation) of the disciplines of teaching and the discipline of research, their concomitant structures and funding [4] and the broad definitions of the base concepts of teaching and research [5]. As long as they are seen as two distinct spheres of academic work, one cannot consider it a teaching-research nexus (TRN). This is further confounded by the fact that higher education institutions perform both functions [6], and is what makes them unique. This is in contrast to purely research-only institutions such as Meraka or the CSIR, or purely teaching institutions such as colleges or technical and vocational training institutions (TVET). Historically these have also formed the basis of measuring a higher education institutions output i.e. number of students graduated and number of publications [4], [5]. It may therefore be more appropriate to speak of higher education institutions, faculties, departments or courses as being research-led or teaching-led and the curriculum as content-driven as opposed to process or methods driven with various continuums between these [5]. Conducting research to inform and improve

one's own teaching practices has classically been labeled as the Scholarship of Teaching and Learning (SoTL) [7]. This however does not constitute a nexus between teaching and research in the classroom [8]. Not only are academics researching their own practices such as with (SoTL), but with TRN they transition from a domain of teaching where the emphasis is on curriculum content; to a realm of student or scholarly research where the emphasis is on research processes and problems [3]. When one considers the nexus between teaching and research, one can envisage teaching as being research driven, or the creating of a conducive culture towards research, both for students and academics, the integration of teaching and research at a departmental or classroom level, or the integration of research in a traditional teaching situation [4]. In practice, the distinctions between teaching and research are not as clear-cut as these, however it is useful to have some kind of model with which to inform discussions. The model as proposed by Griffiths [5] seems to have become the de-facto standard [3], [9][10]. An adaptation of the model by Elsen [9] (Table 1), presents two axes of the teaching/research nexus, with one emphasising teaching versus research, and the other whether it is teacher or student focused. Curriculum interventions can be targeted at any of these quadrants, depending on the required objectives of the course.

Table 1. Curriculum design and the research teaching nexus ([9, p. 79]**) adapted from (Healy, 2005)**



Trowler and Wareham [11] identify seven different ways (dimensions) in which the concept of the teaching-research nexus is explicated. These can be seen as i. learners doing research, ii. teachers doing research, iii. teachers and learners researching together, iv. research is embedded in the curriculum, v. research culture influences teaching and learning, vi. both teaching and research is linked to the university and its greater environment, and vii. teaching and learning influences research. Each dimension presents its own challenges and opportunities. Elsen [9] propose a number of interventions for strengthening the teaching-research nexus in the curriculum, specifically interventions such as group assignments, research projects, workshops and training on specific research skills, as well as presenting their research to other students and the department. As can be seen from the prior discussion, the TRN is no singular concept, but encapsulates a range of interventions targeted at the curriculum that allows various degrees of involvement of both the student and the lecturer, as well as varying degrees of practical research as opposed to theoretical teaching. The following section examines just how the TRN can be strengthened, based on the model by Griffiths/Elsen.

2.1 Strengthening the TRN in the curriculum

Implementing these changes in the curriculum requires a change in the way that lecturers teach their courses, as well as in the way that students learn, neither of which are without risk. Following are some of the opportunities, benefits and challenges of strengthening the teaching-research nexus in the curriculum as outlined by Trowler & Wareham [11] that I have integrated with the dimensions by Elsen et al. [9]. Some practical examples, derived from Elsen et al. [9, p. 71] are presented as follows.

2.1.1 Research-Led (R-L) teaching

This aspect would present an overview of the discipline, concepts of research and theory development, the nature and philosophy of the discipline etc. The aim of this approach is to familiarise students with the content of the curriculum and the research. The benefits of such an approach are that it stimulates a passion for the subject in the student, professionalises the faculty, and informs teaching practices. Challenges with such an approach are that significant energy is spent on research instead of teaching, tutors are required to assist students, and students may feel abandoned.

2.1.2 Research-Oriented (R-O) teaching

This teaching approach would incorporate training on specific research and communication skills, i.e. information literacy, reading, writing, interviewing, presenting and debating. The aim of this aspect is to familiarise students with the required aspects of conducting research, by engaging them with familiar research in the discipline or institution. Elsen [9] calls this *"On familiar territory"*. The results are more task-oriented research that requires greater co-operation between lecturers and students. Some challenges are that students effectively become unpaid research assistants.

2.1.3 Research-Tutored (R-T) teaching

This aspect would examine or critically review specific cases, articles or chapters from the discipline. The aim of this approach is the critical evaluation and discussion of previous research findings, in greater levels of complexity and difficulty. By establishing a research culture, this approach provides for a motivational context for teaching and research. The problem is that research may become prioritized over teaching, and students may feel neglected.

2.1.4 Research-Based (R-B) teaching

The research-based approach exposes students in a research project of the discipline or institution, resulting in a presentation and/or reflection on the research process. The aim of this phase is to induct students into the "community of scholars", and to gain new insights either into the project, the methodology or themselves. With R-B teaching, students are exposed to new concepts, develop new skills and greater epistemological access. Limitations of this approach are that it may be too slow to fit into a typical semester, provides fragmented coverage of the curriculum, may result in poor quality research, and requires lengthy ethical clearances.

2.2 Strengthening the TRN in the undergraduate curriculum

Despite the importance of research in the IS discipline, scant attention is paid to the inclusion of research competencies, especially in the undergraduate curriculum. For example, in the IS 2010 Curriculum [12] there are no emphasis on the development of IS graduate research skills, yet the discipline prides itself in the number of dedicated publications and journals.

Not only is Information Systems research essential for maintaining the identity of the discipline [13], [14], it is essential to the hiring, promotion, tenure and pay scales for academics, as well as being used to rank departments and institutions [15]–[17]. It is more likely that the TRN link is stronger at a postgraduate level, where one of the expected outputs of students are a research project, thesis or dissertation, however it is considered to be most problematic and needed in the undergraduate curriculum [10] where there is limited integration between teaching and research. The trend at higher education institutions is to first introduce students to a research project at Honour's or Master's level, however there is no reason why this cannot be done at an undergraduate level as well. At this institution, there is a dedicated research methods and philosophy module at a third year level. Furthermore, this institution has a specific first year module dedicated to the development of academic literacy for commerce (ALC) that focuses on the development of academic reading and writing and critical thinking skills. The project tried to parallel as much as possible the work that the students covered in the ALC module that related to research and writing skills. It is regular practice that students are given research assignments to conduct at an undergraduate level, yet the development of these skills are left to chance or what the students had learnt at school or what they learn for themselves or from their peers. Approaches that have received favour in undergraduate curriculum, is to bring real-world experience to the classroom either through the use of case studies, especially in business, economics and information systems [18] or real-world projects, such as service learning [19], doing projects for community non-profit organisations [20], bringing real-world problems to the classroom [21], [22]. A direct way to enroll students into the research culture is to introduce a practical research project in the undergraduate curriculum. In a study of such a case, direct benefits in areas of communication, data collection, professional development, personal development, professional advancement, information literacy, responsibility and knowledge were shown [23]. In addition, students at a teaching-led university have shown that introducing a research project early-on increases student motivation, as they see it as real-world skills that they can add to their curriculum vitaes [24]. They recommend that instructors need to consider:

> *"involving students in a number of research-related activities such as class assignments, co-authorship, creation and attendance at conferences, community projects, service learning, involvement across disciplines, gaining a variety of related skills outside the class, and generally encouraging activities that can be included in a student's co-curricular record"* [24, p. 48].

Mustafa [25] emphasises that research projects allow students to explore concepts beyond textbooks and the classroom, and claim that it is a process, for which a systematic framework will allow students to produce better research reports.. Salsman [23] also report greater student and faculty effort in all areas such as developing theories, defining samples, interpreting findings, and preparing written reports, especially if there is an intent to publish the report.

2.3 Level of Inquiry

The TRN can be examined at a societal level, for example where actuality events are discussed and researched in the curriculum, at an institutional level in terms of policy and support [26], [27], or at a curriculum level as outlined above. This paper focuses on the curriculum interventions, and will not therefore consider the faculty or departmental initiatives, nor institutional policies. Suffice to say that the institution has openly proclaimed its transitioning to a research institution [36], with clear policy support in its Institutional Operating Plan [IOP], Teaching and Learning strategies [28] to support and encourage a research culture in support of its strategic and operational plans. These strategies are further encouraged in the Teaching Portfolio [29, p. 4] "reviewing the extent that an inquiry-based approach has been implemented", (6.6) "attempts to include research methodologies for undergraduate students in the curriculum", and (6.7) the" participation by students in publishing and presenting papers at national and international conferences". Further support is provided in terms of the faculties graduate attributes.

3. RESEARCH METHODOLOGY

The idea for the project had started a year earlier, and the plan as outlined in "Introducing the 1st Year Assignment" was conceptualized as a result of experiences and reflections on assignments and activities that I had introduced in the curriculum over the course of the previous year and a half.

3.1 Research Method

The method used for the introduction of the assignments and evaluating the students learning is based on the Experiential Learning Cycle [30], [31]. Experiential learning engages students directly in the subject that is being studied [32] and allows students to directly experience the links between theory and practice, explicates abstract concepts, has a positive effect on students methodological skills, and is appropriate for teaching the practical aspects of research methods courses. Limitations of this approach to teaching is that requires intensive planning and administrative considerations, various consultations and organization[32]. Because of these challenges, this approach is often used in semester or year-long courses. The learning outcomes are also important, as not all experiences involve learning[32]. The theoretical basis of experiential learning is based on six premises [31, p. 194] namely:

i. Learning is conceived as a process and not an outcome,
ii. All learning is re-learning,
iii. Learning requires one to move between modes of reflection and action or thinking and feeling,
iv. Learning is a process of adapting to the world
v. Learning results from synergetic transactions between the person and the environment.
vi. Learning is the process of creating knowledge.

The cycle of Experiential Learning can be described as a repeating cycle of Action → Reflection → Conceptualisation → Application or in simplified form [33] of Act → What Happened? → So What? → Now What? The value in this model is not so much in its theoretical complexity, but in its simplicity of acting and reflecting on ones actions. In that way, I designed and implemented a specific action, and reflected on the effectiveness of such action. In much the same way, students were asked to act (do an assignment), and reflect on their actions. The rest of this paper is a preliminary analysis of the conceptual aspects of what was learnt, and proposing future areas of applications.

3.2 Case Study Method

For this project, a case study method was followed and is considered suitable for exploratory research in teaching or instructional purposes [34] and for researchers to study phenomena in their original context [35]. A case study is a complete account of the actions and behaviours of a full cycle of action, and aims at completeness [36, p. 75]. For this case study, a case record was compiled from the student assignments, meeting

minutes, project reports and my own reflections. The focus of the project was to understand what new skills and knowledge students acquired through this approach, and lecturers and other project participants were not interviewed.

3.3 Data Sources

A number of sources for the case were used to compile the research findings. These are from the articles that the students were required to read, summarise and synthesise, the actual assignments that they had submitted, the Turnitin results, the Facebook posts, and the Google docs comments/reflections and my own personal reflections that were recorded at the time. The numbers indicated in brackets, refer to the number of incidences/students that had commented on this aspect. The Facebook comments (900), and Google doc comments (267) were loaded in Nvivo 10 for coding and analysis.

3.4 Data Coding

The data was coded in Nvivo based on the source i.e. Facebook post or Google Docs, the type of technology that the student was referring to, advantages and disadvantages, as well as distinguishing between the practical and theoretical aspects that the students gained value from.

3.5 Ethical Considerations

All the information that was collected for this study was stored in an ethically sensitive manner. The Facebook and Google sites were created as closed/private groups and only students with the link to the site could access it. Students had to create their own Facebook profiles, and no personal student information was posted. Students were cautioned that the information that they post to Facebook should not contain any personal or institutional references or inappropriate comments and that these would be removed by the project lead.

4. CASE SETTING

The project was implemented in the Information Systems Department at a South African University. The setting was appropriate, as the course allowed for the introduction of the research project in the undergraduate curriculum. Of specific significance is the increasing focus of the institution to transition to a research-led institution.

4.1 Institutional Support for TRN

Historically, the institution where the project was conducted was established as a teaching university, with the majority of faculty appointed as lecturers, and the majority of posts being lecturing or managerial posts. Research output on the other hand is not only encouraged but expected in addition to one's teaching and supervision workload. However, with the recent trends in research funding, and the establishment of a number of research chairs at the institute, research has taken a more important position as outlined in their Institutional Operating Plan [37]. Furthermore, the institutions Teaching and Learning strategies [28] support and encourage a research culture in support of its strategic and operational plans. These strategies are further encouraged in their Teaching Portfolio Development guide [29, p. 4] under Item 6 Scholarship of Teaching and Learning by (6.5) reviewing the extent that an inquiry-based approach has been implemented, (6.6) attempts to include research methodologies for undergraduate students in the curriculum, and (6.7) the participation by students in publishing and presenting papers at national and international conferences. Furthermore, these strategies are further supported by the institutions teaching and learning policies, graduate attributes and portfolio development guidelines.

4.2 Course

The course that I introduced the research project into is a second semester course called "Introduction to Information Systems". This course is traditionally smaller (approximately 400 students) than the first semester course which could exceed 800 students, and is mostly comprised of students repeating the module from the first semester, or those that have timetable clashes. The course is compulsory for all first year students in the Economic and Management Sciences faculty, and in that year comprised students from a number of departments and faculties, namely B.Admin (104), B.Bibl (6), B.Com Accounting (100), B.Com Gen (85), B Com Law (6), B. Ed (7), BSc Comp Sci (93) and BA (15).

4.3 Course Objectives

The objectives of the course is to introduce students to using computer technology to manage information effectively, understand the structure and dynamics of organisations and the role of information systems in them, and be practiced in the workings of a typical business information system. This is quite a broad aim for such a large class, as there are challenges in providing access to a "typical" business information system at a resource constrained institution. Even though these students have historically been given literature review assignments in this module, they have not conducted any research or technology based assignments, besides an introduction to the Academic Writing Process in the Academic Literacy for Commerce (ALC) course.

4.4 Resources

The classes for this course were held in a venue which could accommodate a large number of students but are not equipped with computers or power points for laptops. The students (416) were divided into two lecture groups. The classrooms were normal lecture venues, with audio-visual equipment, but no computers for students. For assignments, students are able to use their own laptops or PCs, as well as those in a number of computer labs, scattered around campus. The library also has a number of computers for students to use.

4.5 Research Project

The project was part of a larger project entitled Mobile Technology for Education in Southern Africa (MTESA). The aim of the research project was to understand how students and lecturers are using mobile technologies in education, as well as introducing students to conducting their own research. The objective was to initiate research in the first year curriculum, and continue this through 2nd and third years and on to the Honour's and Master's Research projects.

5. INTRODUCING RESEARCH IN THE 1ST YEAR CURRICULUM

5.1 Introduction to the research

As the first year students were recently out of high school, I thought it would be an interesting for them to research a current topic that was being debated in the newspapers, namely "Banning Cellphones in Schools (City Press, 4 May, 2012). The topic that was introduced was "The perception on the use of mobile technology in education ", specifically looking at the advantages and disadvantages of cellphone or mobile technology in the classroom.

5.2 Overview of the assignments

As the purpose of the project was to introduce students to computers, and in prior years students experience with computers were only incidental (i.e. using PCs in the library to do assignments etc.), I decided to structure the assignment to give students first-hand experience with some of the more modern tools of computing, such as Facebook, Google docs, Google Scholar etc.

> *"To provide learner with the basic skills and knowledge of computer hardware and software, which will serve as a framework for Information Technology and Information systems skills"* [38, p. IFS132]

The objective and purpose of the assignment was given as follows:

> A*s a first year student, you will need to develop the skills of accessing and using social media and internet services in order to survive in the "IS" world.*
>
> *The purpose of this assignment is therefore to develop your knowledge and skills of social media such as Facebook and cloud (internet) services such as Google Docs.*

The existing curriculum required two assignments, one a group assignment (7.5% of coursework) and the other an individual assignment (10% of coursework). The course outline also allowed for Tutorial tasks (2.5%) as well as a presentation of the group assignment (5% of marks) which we used as well. Furthermore, tutorial tasks were allocated 2,5% of the coursework. A further 5% is allocated for a multi-media presentation of the group assignment.

5.3 Introducing the Assignment

The aim of the assignment was to introduce students to conducting research that is relevant to their lives, in the existing curriculum, and also develop skills of group work, accessing information, using cloud collaborative productivity tools (such as Google Docs) conducting interviews, and writing skills of compiling a summary of two articles and synthesizing them into a coherent evaluation as well as reflecting on what they have learnt by posting on a public forum (Facebook). The topic was introduced in a dramatic way by the lecturer, by confiscating a previously arranged damaged phone from a student in the classroom whose phone was ringing, and dropping it in a jar of water.

5.4 Structuring the assignments

Due to the large number of students, tutors and other people involved, it was necessary to structure and coordinate the assignment as a process of discrete steps throughout the semester in order to build up to the main assignment.

5.4.1 Groups and Tutor Allocation

The course was allocated 22 tutors for the semester. This resulted in approximately 20 students per tutor, and these twenty students were further subdivided into four groups of five students. The head tutor was also appointed as the project coordinator, and was given the responsibility for liaising with all the role-players concerned, and ensuring that the assignments were sent out on time, and marking returned on time.

5.4.2 Tutor Training

Tutors were trained by the librarian in the use of Google Scholar, the and the library databases, and by the writing centre coach in writing an article summary and synthesis. The way I did this, was to give each tutor (20 in total), one seed article, from which they had to identify and locate four other related articles for their groups. The tutors were then required to share the articles with each group, one week before their next tutorial session, so that the students could discuss the article at the session.

5.4.3 Templates

In order to ensure consistency across the assignments, tutors were provided with a word document template that was structured according to the assignment, to provide their groups. The benefit of standardizing the document is that it provides consistency in reading and marking, as well as allowing automated importing into document analysis software such as Nvivo.

5.4.4 Literature Review

In order to structure the literature review, I felt that it was important that the students research mobile technology in education, in order to have some idea about current research on the topic and to learn how to search for and find suitable articles, prior to conducting their research. This aspect related to the course Learning Outcome 2 *"Be able to use the computer to organize and manage information".* The approach that I developed for the literature review for a large class of students and their tutors, was to identify seed articles, one for each group. This limited the risk that a number of students used the same articles, or were tempted to copy somebody else's assignments.

I wanted to have a focused review of these topical areas, and reasoned that if I had given the students the first article, and they selected an article based on this, then it would complement the study, and the students understanding of the topic. The groups had to read and discuss the key issues of this article at their next tutorial session. The aim was to initiate dialogue and communication in the group. Based on their discussion, the groups then needed to find and download a seminal article that referred to a key issue that they identified in the article. In order to develop their capability to find this article, the students then had to access the university databases or find other ways to get the article. In order to learn to use Google Docs, the students had to upload a copy of the article.

5.4.5 Writing a summary

The group had to read the article that they were provided and the one that they downloaded, and write a summary of the each. A step-by-step process was outlined by the writing centre director (Adapted from [39]). These steps (in short) are to 1. Divide the text into sections, 2. read these sections, 3. reread these sections, 4. Write a sentence for each section, 5. Write a thesis statement, 6. Draft the summary, 7. Check for accuracy, and 8 revise the draft. This gave the students a brief overview of how to conduct the actual assignment.

5.4.6 Writing a Synthesis

In order to develop the competency of integrating information, the group then had to write a synthesis of these two articles, as part of the assignment. Again the writing centre provided the tutors with training in writing the synthesis based on a YouTube clip [40], which they then discussed with the students at the next tutorial, as well as assisting me in developing a rubric for the assignment to give to the tutors to mark. I decided to allocate both the students group assignment and the individual assignment to this topic. Even though the curriculum does not examine e-Learning, the topic was appropriate as there had been talk of schools banning cellphones, as well as in order to provide the students an introduction to social networking concepts which is part of the curriculum. The group assignment was a literature review summary and synthesis of two articles relevant to the topic.

5.4.7 Turnitin

As a final Quality Assurance check, groups were required to submit their article summaries and synthesis to turniting in order to check the originality score.

5.4.8 Facebook Post

The individual assignment required the students to create a Facebook account (if they did not already have one). They then had to join the MTESA (Mobile Technologies for Education in Southern Africa) closed group that I had created, and respond (post) the three key questions namely:

> *1. How are mobile technologies actually used in the classroom?*
>
> *2. What are the perceived benefits of mobile technologies in the classroom?*
>
> *3. What are the perceived disadvantages of mobile technologies in the classroom?*

This required students to learn how to create a Facebook site, join a group, think of the usage of cellphones in the classroom, in their own context and to post some comments publicly.

5.4.9 Cloud Services (Google)

Students were also required to create a Gmail account (if they did not already have one) and upload the two articles that they had summarized. The assignment was due in week 9. Furthermore, the students had to collaboratively edit a document (Excel spreadsheet) on Google Docs.

> *The objectives of this part of the individual assignment is …to use Google drive where you can learn to edit a document collaboratively (together with your friends or class). You can of course use Google Docs for storing all your assignments etc., and you are free to explore the other features.*

The students had to find their student number on the list, enter their Facebook email that they had created, and their Gmail account detail. These I needed in order to link up and allocate marks for both the Facebook and Google docs assignments. Lastly, students were required to write a comment/reflection on what they had learnt from this assignment.

5.4.10 Group Presentation

As a final aspect of the assignment, each group had to present (Week 10) in their tutorial group, a short presentation on the research that they had conducted. The tutors were provided with a rubric for marking these presentations, which became part of the students tutorial marks.

5.4.11 Conducting Interviews

The initial project proposed that the tutors/students are trained in conducting interviews, and that they would interview either a parent, or school teacher on the use of cellphones in schools. In practice however, it was found that this was too high a workload for the first year students to manage, and it is proposed that this aspect be conducted in the 2nd year curriculum. Also, as students will be focusing on their major in the 2nd year, it may be important for research-led courses such as information systems or management, to ensure that such an activity or tasks are included in the 2nd year of study.

5.4.12 Marking the assignments

As the assignment was going to be marked by the 20+ tutors, it was important that I provide them with an appropriate way of evaluating the assignments, and thus sought to identify a suitable mechanism for submitting the assignments electronically, as well as marking them. The challenge with the Facebook page, was for me to provide the Tutors with the 400+ students postings in order to mark them. The solution was in using NVivo's web importer to import all the Facebook posts, and then sort the posts per student, and per group. I also needed the Google Docs spreadsheet in order to link the students posts with their student numbers (as a primary key). I could then give each tutor a printout of the students in his group for marking. The site got over 900 posts on the topic by the students. The assignments were downloaded, and given to the tutors to mark. I also downloaded the Turnitin results, and gave the tutors the TIN percentage for each of their groups assignments. The rubrics for both assignments were created in conjunction with the writing centre, and the tutors had to attend two workshops, one on accessing digital resources by the faculty librarian, and the other an introduction to summarizing by the head of the writing centre.

6. REVIEW OF THE PROJECT

The primary approach followed in this case, is a research-based (RB) approach, achieved by introducing a research project in the curriculum resulting in a written submission and oral presentation and reflection on the project. The aim of such a project is to introduce students to research techniques, gain hands-on experience of modern technologies, evaluate student's learning, and to learn more about the project. This concurs with the work of Elsen "to induct students into the "community of scholars", and to gain new insights either into the project, the methodology or themselves" [9]. There was also a limited amount of research and academic literacy skills development which are considered Research-Oriented (R-O). This is what Elsen calls "on familiar territory" and the aim is to familiarise students with research techniques. In addition, further contributions were made in terms of the R_B approach, as well as the use of technology.

6.1.1 What students learned from the assignment

The topic that the students were required to research was "The advantages and disadvantages of mobile technology in higher education". By nature the primary learning by the students was about topic. A number of students referred to the topic and assignment in their reflections/comments (81). Students reflected on how mobile technologies can assist in storing and getting access to information (22), how to incorporate mobile technologies inside and outside the classroom, the advantages (11) of mobile technologies, as well as disadvantages (7) of mobile technologies in the classroom (3).

> *"From this Assignment I learnt that actually I can take advantage of my mobile phone for my Academics in class and also learnt of how to use the Google drive, Actually all in all is that technology has made life to be simple to us" (Student15)*

and

> *Mobile technologies helps students to get more understanding about a topic through finding more explanation via the internet search engines. They are also a bad influence because some students use mobile technology to chat in the social networks during the cause of teaching in the classroom. (Student180)*

From a theoretical perspective, students learned how mobile technologies can be used in the classroom

> *"I have learned that the use of mobile technologies has many recognizable advantages although it has its disadvantages. I learned that I can utilize mobile technologies for the better of*

my academic career. Mobile technologies can make things so much better for us as students. I learned the various ways in which mobile technologies can be utilized to help me perform better academically. I learned that students also use mobile technologies for the wrong reasons, introducing its disadvantages. Therefore, if we use mobile technologies for the right reasons it will benefit us greatly." (Student413)

6.1.2 Article Summaries

From the initial seed of twenty articles, students researched and accessed an additional 60 articles on the topic of mobile technology in education, which they summarized. Students also learnt how to write a synthesis of two articles. The average originality score for these summaries were 24%, and there were approximately 20 group assignments out of 27 groups that exceeded an originality score of 30%. The students did well with this assignment and demonstrated good research, writing and summarizing skills, as they had to find their own articles on the topic. Students and tutors both learnt how to discuss key issues in an article, identify and download a related article, write a summary of two articles, and combine these into a synthesis. These are essential skills for a novice researcher, and it is important that these skills be incorporated in the undergraduate curriculum.

6.1.3 Facebook Posts

From the 400 students over 900 comments were posted on Facebook. One student commented that he/she did not get any value from the Facebook assignment.

"I think this Facebook thing should be cut out and its not really helpful in any way" (Student45)

The following comment posted on the usage of cellphones in the classroom are indicative of the types of posts made by the students.

"Mobile technologies are used for different purposes in class such as accessing slides for different subjects, accessing previous question papers for exam purposes, reading and sending e-mails, administrative purposes(time-tables, assignment due-dates, updates on a subject), Online Dictionary (for meaning of words) and entertainment purposes(listening to music and chatting)." (User25)

A significant post on the some of the disadvantages posted were

"mobile technology causes some students who r corrupt by nature to be more corrupt for example with the aid of mobile technology, now some students may cheat on a test using the net. Some bully others by cyber bullying or may even engage in sexting!!!!!!" (User 86).

From this assignment, students learnt how to create a Facebook site (if they did not already have one), locate and join a Facebook group, and post comments on a group site.

6.1.4 Google Drive/Docs

From the assignment, students learnt what Google docs was, how to use it to capture and share information. Students also learnt about Google drive, what it is, how to use it, how to upload (important) documents, that it is resourceful, and can be used as a data backup.

Technologies in the classroom are more prevalent than it used to be in the past. These technologies allow easier communication for academic purposes and allow users to find information more easily via the internet. Cloud saving services such as Google drive could be used to access data form anywhere, this also allows relatively large files to be accessed by many. (Student74).

Some students also indicated that they learnt about cloud computing (4), and that one can access the same data from different platforms.

6.1.5 Practical Skills

Students (3) indicated that the assignment improved their skills of using mobile technology in an education environment.

"this assignment thought me that I can develop my new skills of using a computer in the real life situations. For example my background of my education I did not have an chance to consume internet access freely and learning how to use social networks. Therefore my knowledge has improved on the world of Mobile technologies cause my researching skills improved, and internet communication skills improved. To add because I were given a chance to create Facebook I also learn that I can express my facts an views to other people by writing to one another. Nevertheless this assignment really improve my skills on adapting the world of today Modern of using Mobile Technologies and I'm pleased looking forward from you guys on helping me again to improve my skills and knowledge. (Student17)

The kinds of skills that students indicated that they had developed were using computers, using social networks, researching skills, communication skills, creating Facebook pages, adapting to the world of mobile technologies, computer literacy skills, improve effectiveness of research projects.

6.1.6 Practical value of assignments

Students found a number (13) of aspects of the assignments were beneficial to them. Specifically, students found that mobile technology can be beneficial for social networking purposes, for accessing the internet in the classroom, the use of Google drive for storing and retrieving documents using Google docs, and using Facebook for classroom assignments. They also found the assignments helpful (n=15) for storing and sharing information with their groups, editing documents online, communicating with lecturers, and submitting of assignments. Students found that it was easy to store and use information using Google drive, and that it made their studies enjoyable.

"from the assignment I have learnt that mobile technologies if used appropriately in classes can be very useful to students and can make ones studies enjoyable and easy at all times" (Student2)

Students found that they can use Google docs for storing important documents and information (3), and that Facebook can be used for important aspects and not only for social usage and can connect many users. Students felt that the assignments improved (10) their use of mobile technologies, and if used properly can improve learning, productivity and academic performance. Students found that Google docs was useful tool for the classroom, and that the tools can make studies enjoyable

Two students even commented that by doing the assignments they got to love Google docs (Student42) and Information Systems (the course) (Student43).

6.1.7 Group Work

Three of the students reflected on the challenges of group work, that it was not as easy as they thought, that different members bring different aspects to the group assignment, and that it requires everyone in the group to contribute in order to make the

assignment a success. From the group work, one of the students learned more about him and how to handle the situation.

> *"I have learnt that group assignments are not as easy as I thought it would be. Members in the group have different personalities, responsibilities and priorities which make it quiet challenging to work in a group. As the assignment proceeded I have learnt to handle myself better and to compromise in a situation". (Student21)*

One student commented that they learned not to trust their fellow group members:

> *I learnt not to trust people and to always keep tabs on other people's progress (Student40)*

The students were not specifically asked to reflect on the group work aspects of the assignment, and these comments may therefore not be indicative of the groups experience of the assignments.

6.2 TRN APPROACH

Research interventions can be incorporated progressively in the teaching curriculum [9], either in a module or over a period of a number of years. This can be implemented through a systematic approach of lectures, tutor-led research, research orientation and active participation in a research project.

> *In practice, courses can consist of a combination of activities with various emphases. For instance, a course can start with a lecture on a specific problem, or a recent research result and then discuss various ways to research this issue, after which students do some research in small groups and, in a concluding session, are debriefed by their teacher* [9, pp. 79–80].

In this case, the following phased approach in strengthening the teaching-research nexus in a first year class was adopted.

6.2.1 Research-Led

The research professor/director conceptualises the research project or programme, aligned with the curriculum, relevant to the students, and selects an appropriate module or course to introduce the research project. Topics are defined, and areas of research identified. In this case, a number of seed articles were identified for each student/tutor group, from which students were required to conduct further research. The topics and research are introduced to the students in an appropriate manner in order to gain their interest in conducting the research. Marks are allocated for the research project, and this needs to be a significant portion of the semester marks in order to make it worth their while.

6.2.2 Research-Oriented

The next step would be Research-Oriented in order to provide students with the experience in applying some or all of the research processes, such as interviewing, researching, writing, collecting data etc. In this case, tutors and students were introduced to the research tools that they needed to conduct their research, such as library databases, Google scholar, and for larger research projects a reference management tool such as Endnote, Refworks or Mendeley. Students were then required to locate and download a related, relevant article for evaluation.

6.2.3 Research-Tutored

Tutors and students are trained on the techniques that they require to critically evaluate prior research in the context of the discipline. In this case the tutors and students were trained in writing an article summary and an article synthesis. In other cases e.g. in later years, students can be taught to write abstracts, annotated bibliographies, methodology sections etc.

6.2.4 Research-Based

The fourth step would require students to actively participate in a research project and publish or share the results. In this case, students used the tools that were introduced to them (Facebook, Google docs etc.) to learn how these tools can be used in a classroom environment, and were then asked to present what they had learned to other students in their groups, and to share their newly acquired knowledge by posting on a social networking site (Facebook).

It is envisaged that this process may be different, depending on the level of students i.e. first, 2nd or third year, however the process outlined above catered for all the aspects of the TRN and was feasible and achievable in the time allocated for the course, and for the large number of students.

7. NECESSARY CONDITIONS

Brew [41] developed seven criteria for evaluating the integration of teaching and research in the curriculum. These are listed as University Commitment, Faculty Support, Departmental Encouragement, Curriculum Design, Staff Capability, and Student Awareness. A thorough examination of these contextual aspects are beyond the scope of this paper, yet it may be of value to reflect on some of these aspects which may have a direct and indirect impact on the success of such an intervention. For those institutions/faculties/departments and lecturers considering introducing such a project in the curriculum, I wish to reflect on some of these aspects, both as a form of encouragement and caution.

7.1.1 University Commitment

Despite the clear support in terms of policy statements, when it came to funding the research of this project, the teaching and learning division had not made provision for such activities that year, despite it being one of their key strategies. To roll out TRN activities, the teaching and learning division would need to budget for this, as well as departmental HOD's and Faculty Dean's to support such initiatives, especially if it impacts more than one department [9]. Financial support will become essential to conduct further research on such projects, and to fund other lecturers/tutors and sponsors involvement.

7.1.2 Faculty Support

The approach followed in this particular case, necessitated the involvement of multiple stakeholder in the project, with the research professor/director, the lecturer concerned, the ALC lecturer, the faculty librarian, the writing centre director, the tutor coordinator, tutors, administrator and students all contributing to the successful outcome of the project.

7.1.3 Departmental Encouragement

It was found that departmental support is essential in encouraging lecturers to introduce research-led aspects into their curriculum [9], in spite of the institutions increasing emphasis on research and the teaching and learning divisions strategies of research-led teaching.

7.1.4 Curriculum Design

The programme has outlined a way in which research can be embedded in the undergraduate curriculum. It should be noted that a suitable first year course should be selected that exposes the maximum number of students in the faculty. Care should however be taken that research projects of such nature are not introduced into more than one Department per Faculty, as students indicated

a high workload that would not be manageable if they had to conduct more than one project per year.

7.1.5 Staff Capability

Furthermore, the use of multiple technologies such as Facebook, Google Docs, Google Scholar, Excel, Turnitin, and Nvivo made it a complicated project to implement, and knowledge/experience of these technologies and tools are essential for the lecturer/research director concerned. Such technologies are continuously changing, and assignments/projects would need to be continuously updated in order to cater for such new technologies. Full involvement of the lecturer in such a research project is also necessary in order to foster buy-in and commitment to such a large-scale project. In addition the lecturer needs to be involved in apportioning the available marks for assignments. An additional benefit of such a research project for the lecturer concerned is that the lecturer does not have the workload of administering and marking such assignments.

7.1.6 Student Awareness

One of the challenges found with this project, was students lack of awareness and importance of research as a practical skill, as well as possible career opportunities in research, and the perceived difficulty of conducting research. Students are more inclined to continue with postgraduate research if they realise that the process is not as daunting as they perceive.

7.1.7 Role of a Research Professor

Despite the positive experiences by the students, and the development of practical skills, the project was not continued the following year. This may be because it requires the dedicated input by a research director/coordinator, and partially because it was not embedded in the curriculum. In order for such a programme to be sustainable, and embedded in the curriculum, a research director or professor may be necessary [6]. His/her role would include the need to implement and manage such large-scale research projects in the faculty, as well as develop competencies amongst lecturers in designing their own research assignments.

7.1.8 Required Facilities/Infrastructure

At this institution, there are also no classrooms large enough (200 seats) that are equipped with computers and suitable for introducing such a research project. The system of tutors [42] was therefore one way that we could circumvent such limitations. This does however require the faculty/institution to invest financially in a tutor-based system.

7.1.9 General Challenges

Some of the challenges experienced with this project were the time that it takes to get research ethics approval, and it is recommended that only one such large-scale project be run at any given time in the faculty. This is important, both in order to manage the scope of the research that the students conduct, as well as to prevent overloading the students with research assignments, as such a project also increases students and tutor workload.

7.1.10 Scope of Activities

In the end, the project was overly ambitious in terms of what the students were able to accomplish in one semester. One aspect that needed to be removed was the actual conducting of interviews on the topic. This opens the opportunity of conducting interviews (or empirical research) at a second-year level, and then possibly analysing these outcomes in third year research methodology module.

8. CONCLUSION

This project introduced the practical skills of conducting research in a large class (>400) of first year students through the cooperation of a research director, lecturer, writing centre, librarian, tutor coordinator and tutors, as well as conduct large-scale practical and theoretical research on the use of mobile technology in education. From the students posts and comments, they indicated that they had learnt a lot about the topic of mobile technology in education. This also included their own practical use of social networking tools such as mobile phones, Facebook and Google docs for educational purposes. In the process students and tutors were also coached in conducting a literature review, doing a summary and synthesis, using online tools, using a rubric to evaluate the students work and reviewing their presentations. From a project perspective, the team learned what kind of research assignments were feasible to introduce to a first-year group of students, as well as the most suitable way to do so in an environment constrained with lack of computers in the classroom, as well as sufficient lecturers and tutors. In order to implement and manage such programmes in future, institutions may need to consider appointing a dedicated departmental or faculty-wide research professors[6] , to budget for such activities and to consider the required resources and infrastructure. In conclusion, it was found that for such a programme to be sustainable, it needs to be aligned with the institutions research strategies and policies, and needs to be actively supported by deans of research, teaching and learning, faculties, heads of departments, and lecturers concerned.

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Errors Made by Students When Designing Finite Automata

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ABSTRACT
Many computing or computer science degree programmes include at least one module where students are required to design abstract computing machines to recognise words in given languages. These kinds of design tasks are difficult to teach and to learn. This research study focused on the easiest of these design tasks and was an initial attempt to understand the types of mistakes that students make when designing Finite Automata (FAs) to recognise words in given regular languages. Students in two Theoretical Computer Science modules were asked to complete five design exercises. Ten students from a target population of 573 students submitted solutions. The sample was small but meaningful results can still be achieved from small samples in these kinds of studies. The students' solutions were compared to the "correct" solutions. Most of the study group could do some of the easier exercises but the number of incorrect solutions increased as the difficulty of the exercises increased. Common errors included treating FAs as non-deterministic, creating extra unnecessary states which made for complicated and confusing designs, difficulty in processing the remainder of the input string after an accepting state has been reached and general confusion when dealing with more complex problems. Future research in this area should be designed so as to be able to probe more deeply why the students make the errors that they do.

Categories and Subject Descriptors
F.4.3 [**Mathematical logic and formal languages**]: Formal languages—*Classes defined by grammars or automata (e.g., context-free languages, regular sets, recursive sets*); K.3.2 [**Computer and Information Science Education**]: Computer Science Education

General Terms
Human Factors, Languages, Theory

Keywords
Theory of Computation, Finite Automata, Errors, Misconceptions

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1. INTRODUCTION
Many Computer Science programmes teach a course in Theory of Computation (also called Theoretical Computer Science, Formal Languages and Automata Theory (FLAT), etc.) These courses typically require students to design Finite Automata (FAs), Pushdown Automata (PDAs) and Turing Machines (TMs) to recognise languages of the relevant class. At UNISA we have two modules, COS2601 Theoretical Computer Science II and COS3701 Theoretical Computer Science III, which require the students to design automata (FAs, PDAs and TMs) to recognise given languages. In COS2601 FAs are a core concept in the module, while in COS3701 understanding and being able to design FAs is considered "required knowledge". In both of these modules the students struggle to design correct machines although they do often make some progress at designing these machines. The aim of this research project is to try to determine what errors our students make in designing these machines. A longer term goal is to understand why they make these errors and to try to use the knowledge of their misconceptions to assist us in our delivery of the material.

In the next section, Section 2, we discuss two aspects related to this project: cognitive process and change, and the teaching and learning of FAs. Section 3 presents the methodology applied in this study. Section 4 presents the exercises given to the students. For each exercise a problem statement, a solution and a discussion of the students' attempts are presented. Section 5 discusses some common errors made by the students. In Section 6 some ideas for future work are presented and Section 7 summarises the study.

2. RELATED WORK

2.1 Errors from a cognitive viewpoint
There is sometimes a view expressed that either students do, or do not, know course material [35], although a third option has been suggested where students have some conception of complex fields like Computer Science, although these conceptions may be incorrect [35]. Such incorrect conceptions have also been termed alternative or inaccurate conceptions, naive conceptions, alternative frameworks, or preconceptions [12, 19, 20, 28], giving a view on how such ideas have been perceived by researchers. Even though such alternative conceptions may be inter

nally inconsistent and context dependent, they remain capable of controlling a student's approach to a problem, and may be resistant to change [39]. There is the realisation that often errors are not random, and that they may in fact be systematic – not that the student cannot follow the required procedures very well, but that they are following rational (to the student), but wrong, procedures [5, 23]. Thus such errors made by students in building FAs may be a result of inaccurate or non-viable mental models of automata [8, 19, 35, 36, 38]. It has been suggested that these

mental models may be based on how FAs should look rather than on what they mean [5]. Also, imprecise mental models may have developed due to previous conceptions or teaching that does not ensure that newer conceptions are not built from muddled previous ones difficulties that can be exacerbated in distance learning environments [17]. These poorly formed conceptions can then lead to problems later as they become barriers newer material (like building PDAs) have to negotiate [17].

Learning can be seen as an interaction between the ideas that a student already holds and the new data that is being supplied [28]. Key factors in determining whether old ideas will be replaced by new ones, or old conceptions assimilated by or accommodated within new conceptions, are (i) the status that existing and new conceptions have; and (ii) how they are judged in terms of the evidence a student has at his or her disposal [16, 28]. Conditions that can promote the required conceptual change have been proposed by several authors [16, 39]. It does need to be remembered, though, that any conceptual change is a gradual process [22].

It follows, then, that to promote effective teaching and learning, there needs to be some knowledge of the processes of conceptual change. This, together with an understanding of the errors that students make, can then be explicitly addressed by helping them to build appropriate mental models [3, 19, 34, 35, 36]. It is clear that students must be able to identify misconceptions if they are to correct them [22]. One note, does, however, need to be made – that some errors or omissions could simply be due to carelessness, alternative interpretations of the language required, or faulty reasoning rather than some underlying misunderstanding of FAs [27, 29, 33, 34].

Work on the misconceptions prevalent in Computer Science topics have often been focussed on those that have to do with programming (see, for example, [3, 11, 17, 20, 29, 31, 33, 34, 36, 38]), although studies have also been done in the fields of algorithms and data structures [10, 21, 25], software engineering [35], understandings of the CPU [19], and the nature of Computer Science itself [4]. However, there is little work done around the errors in the construction of FAs, with [27] providing a first attempt at identifying the difficulties students face. Some work has also been done in the identification of misconceptions in the application of pumping lemmas [32].

2.2 Teaching and learning FAs

Students often find mastering these foundational FLAT concepts challenging (as they can be very abstract, and thus overwhelming), and even boring (as there is a perception that the field is not only dated, but that it has little current applicability in the real world) [1, 2, 6, 7, 14, 27, 37]. This can lead to demotivated and frustrated students [26] who retain little of what they have learned [14]. Problem-solving skills, or rather the lack thereof, have been identified as one of the major contributors to the difficulties associated with building FAs [27]. This poor level of problem-solving ability can lead to the logic errors that were found to be prevalent [27]. Furthermore, students could be using mechanical 'plug-and-chug' approaches without understanding the logic of the process [8, 32].

In response to this, several teaching approaches have been proposed to overcome these challenges, as well as to assist in the building of better mental models of FAs [1, 6, 8, 18, 26, 27, 29].

- Constructivist teaching strategies and active learning: This includes the need to help students with immediate feedback at each stage of the process of building FAs so that they can better develop problemsolving skills (something that is very difficult to implement in a distance learning environment).
- Visualisation tools: The point of these is to assist students in conceptualising FAs and how they work by providing an alternative view, allowing them to experiment with the concepts by testing them on various input strings and receiving immediate feedback. Such approaches build on the principle that abstract models can become concrete when students can interact with them [15].
- Link to current Computer Science applications: This could include using knowledge of programming as a motivation for the exploration of FAs as well as the use of its application to real-world problems.
- Intelligent tutoring systems: These provide students with individualised assistance, tailoring the route through the required material based on how the student is progressing.

It is expected that such approaches will allow students to see where they are going wrong and lead to the motivation required to build a complete, correct, solution [13]. Extensions have been added to JFLAP (one of the more popular visualisation tools [26]) that allow instructors to record the process used to build an FA and so possibly begin to understand the source of misunderstandings and inefficient strategies in the development of FAs [30].

3. METHODOLOGY

A single, exploratory case study approach that focused on categorising students' errors in designing specifically FAs was undertaken.

The data that we needed to collect to do the analysis was students' attempts at designing FAs to recognise given languages. We considered using students' answers to exam questions as the raw data for the analysis but decided against this for a number reasons. Getting ethical clearance and permission to use this data seemed to be a daunting task; the mechanics of collecting the data from the exam scripts was going to be a problem; etc. but more importantly we were not sure that we would get good data when the students were more focused on earning marks under time pressure than actually attempting to answer the questions to the best of their ability. We thus decided to design specific tasks for the students to complete and to make these tasks available to the students at an appropriate time in the semester. The study received ethical clearance (Ref: 175/IDS/2014) and Senate permission to conduct research using UNISA students (Letter dated: 17 November 2014). The invitation to participate, the design exercises and the Informed Consent document appear in Appendix A. The design exercises and solutions to these exercises are presented in Section 4. When we set the questions, we intended that they would be progressively more difficult (question 1 being the easiest and question 5 being the hardest). However, as we did not actually work out the full solutions at that time, question 4 was more complicated than we had expected as it could be seen as ambiguous, and could be interpreted in different ways.

The sample for this study was a convenience sample of all of the students registered for COS2601 (370) and all of the students registered for COS3701 (203). We believed that even if the response rate was low (as we expected it to be based on previous

experience of doing research on our students), we would get enough interesting data for analysis.

In mid-February we uploaded the invitation to participate, the design questions and the Informed Consent document onto the module pages of the learning management system and sent out an announcement asking the students to assist us with our research. The students were given one month in which to attempt and submit their solutions.

The timing of the announcement was around the time the COS2601 students should first be encountering FAs and also about the time that the COS3701 students should be working on their assignment 1 which included designing an FA. As an incentive to get the students to respond we promised that they would receive their marked attempt back as well as a discussion of the correct approach and answer. The first response from a student was received the next day! Unfortunately this student's enthusiasm was not matched by other students and only 10 students submitted solutions by the deadline. Although this is not a large number, such studies of errors and misconceptions have previously been based on small samples [20, 23, 24].

4. STUDY EXERCISES AND RESULTS

4.1 General comments

Ten students submitted solutions (and gave consent for their solutions to be used in the study), providing interesting responses from which we learnt a few things.

In particular, we noted a few things which should be addressed or at least considered before redoing the study:

1. The definition of a **Finite Automaton** or **FA** in the prescribed textbook [9][p 55] is explicit that FAs are *deterministic* and hence an edge is required for each alphabet symbol from each state. The concept of non-determinism of FAs is only introduced later and then Non-deterministic Finite Automata (NFAs) is used to denote these machines. In designing the exercises for this study we used this convention. It might have been better if we had explicitly asked for deterministic FAs to be designed as some students had states with fewer outgoing arcs/edges than alphabet symbols and we cannot tell whether this was deliberate; an indication of not understanding the definition or an error.
2. In setting the exercises we assumed an alphabet $\Sigma = \{a, b\}$ but did not explicitly state this. This seemed to cause a few students some degree of concern although 9 of the 10 students simply used the alphabet $\Sigma = \{a, b\}$. Respondent 9 was the exception. In any future work we need to be explicit about the alphabet to be used.
3. As mentioned previously, question 4 was ambiguous and because of this was possibly a bit more complicated than was intended. If we had actually worked out the solutions before sending out the call for participation then we would have picked this up and could have asked a different question or been more explicit in this instance.
4. In this study, mainly due to the small sample, we made no attempt to consider the responses of the COS2601 and COS3701 students separately. In future, it would be good to be able to do this to see if there are significant differences in the two groups.

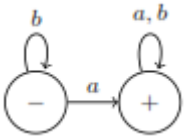
4.2 Questions and Responses

The solutions submitted by each student were analysed by the authors. Table 1 in Appendix B gives an overview of the students' attempts.

Question 1 *Design a Finite Automaton to recognise any language that has at least one a.*

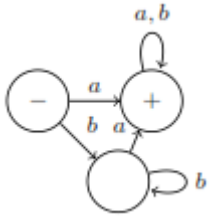
A regular expression for this language is **b*a(a + b)***.

An FA which recognises this language is shown below.



Eight of the ten respondents designed FAs that satisfied the requirements of the question. It is a bit concerning that two respondents could not design an appropriate FA.

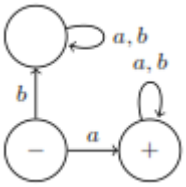
It is interesting to note that two of the respondents designed a similar correct but over-complicated FA with an extra state.



Question 2 *Design a Finite Automaton to recognise any language which starts with an a.*

The regular expression for this language is **a(a + b)***.

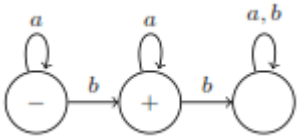
An FA which recognises this language is shown below.



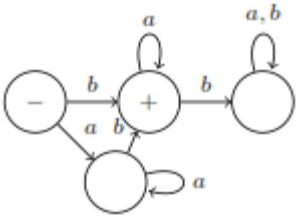
This question was intended to be slightly more difficult than question 1. This seems to be reflected in the responses. Five of the ten respondents designed FAs that satisfied the requirements of the question. Two of the remaining respondents had FAs that were correct if one accepts that they knew a *b* in the initial state should lead to a rejecting state and chose not to draw this rejecting state and its associated edges. Another respondent drew the rejecting state but did not include loops at that state to consume the remainder of the string. This again could indicate understanding but choosing not to draw "useless" transitions. The remaining two respondents seemed to be confused.

Question 3 *Design a Finite Automaton to recognise any language that contains words which have exactly one b. The regular expression for this language is* **a*ba***.

An FA which recognises this language is shown below.



Four respondents produced the expected FA for this question. One respondent (respondent 2) produced an FA which would solve the problem but has an additional (unnecessary) state as seen below.



This solution suggests that the respondent recognizes that words starting with an *a* and words starting with a *b* should be handled differently but does not know quite how to do this. Respondent 5's solution also displays this feature but introduces even more unnecessary states and also drops some edges that are required to define a DFA.

The other three respondents' solutions are not correct.

Question 4 *Design a Finite Automaton to recognise any language that contains words with at least one ab and one ba. Note that the ab must appear before the ba.*

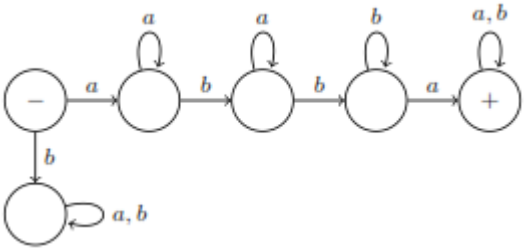
This question was supposed to be slightly more difficult than question 3 but actually turned out to be quite a bit harder as it is not stated precisely. There is some degree of ambiguity. In re-considering the question we found three different ways of thinking about the solution. These are discussed below.

Case 1 The shortest legal word in this language would be *abba* – this word has an *ab* and a *ba*.

Now consider a word like *aaabaaaba*. Is this a word in the language? Certainly there is an *ab*. The question is whether the second *b* in the string is part of an *ab* or part of a *ba*. The simplest interpretation seems to be to treat the second *b* as part of a *ba*. The word then has some as followed by an instance of *ab* followed by more *a*s and then a *ba*. Under this definition the word would be in the required language.

A regular expression for this language would be **a*(ab)a*b*(ba)(a+b)*** and a word in this language could look like *aaaaaabaaaaaaba* or *aaaabaaabbbbaaa*.

An FA for this case is shown below.



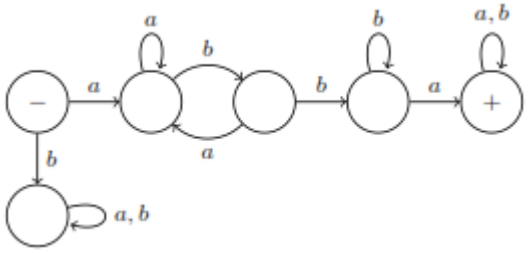
Case 2 This case differs from case 1 in that the second *b* in the string could be considered as part of a second *ab* rather than part of a *ba*. Under these constraints a word in the language would have to look something like *aaaaabaaaabbaaaa*.

A *ba* would have to appear after a b in the word. Words in the language described in this case could look like *aaaabbbbbbaaababbbba*
or *aaaababaaaaabbababababaababababaaa*.

Once again the shortest word in the language needs to have 4 characters and is the word *abba*.

A regular expression that describes the language for this case is **(a*(ab))+b*(ba)(a+b)***. The first part of the regular expression **(a*(ab))+** caters for substrings like *aaabaaabaaaaaaaaab* etc. with the shortest substring being ab. The second part of the regular expression **b*(ba)** caters for strings like *bbbbbba* etc. with the shortest substring here being ba. The last part of the regular expression **(a+b)*** deals with any combinations of *a*s and *b*s after at least one *ab* followed by at least one *ba* has been read.

An FA for this case is shown below.



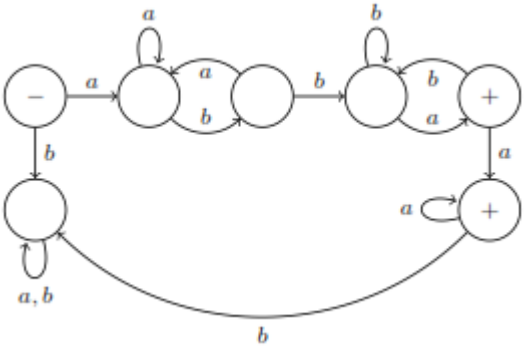
Case 3 Another possible interpretation of the question is that all instances of *ab* have to precede all instances of *ba*.

The shortest word in this language would once again be *abba*.

Other words in the language are *abababababba* and *aaaaababababbbbbbbbabaaaaaaaaaaaa*.

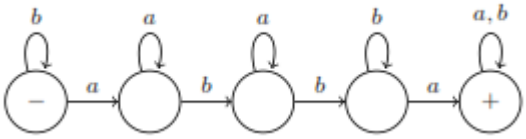
A regular expression for the language presented in this case is **(a*(ab))+(b*(ba))+a***.

An FA which recognises this language is shown below.



Based on the responses it seems that all of the respondents interpreted the question as requiring a solution where at least one *ab* appears before any *ba* and reflects a Case 1 situation above. In addition, it seems that all respondents realised that the shortest word in the language would be abba although only one of them explicitly stated this.

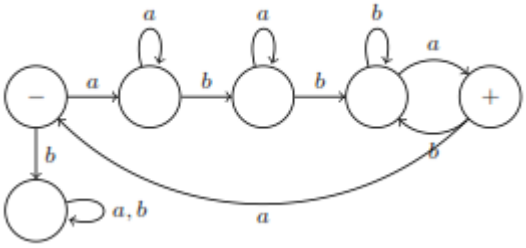
This question seems to have been the most difficult (or most confusing) question of the set. No respondent managed a completely correct solution to the problem. One respondent would have managed a correct solution if they had not left out the b edge from the initial state (thus effectively building an NFA instead of a DFA). Five respondents included a loop on a b in the initial state as shown below.



This would allow acceptance of words which begin with a *ba* and so would not meet the requirements of the given language.

It was interesting to note that one of the respondents designed a Transition Graph (TG) to solve the problem. They did not, however, use the TG to find the correct Regular Expression (RE) or to build the FA. It is not clear whether the respondent knows the difference between a TG and an FA.

Respondent 6's solution was partially correct (see below) and would have accepted many words in the language but because of the edges leaving the final state would not have accepted all words in the language.



He/She seems not to have recognised that all that was necessary would have been to "consume" the remainder of the input string after having reached the accepting state.

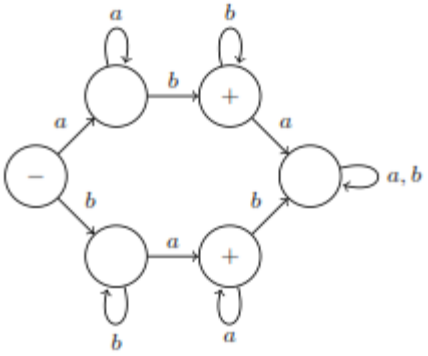
The other two solutions were much further from being correct. One essentially only tackled the minimum word *abba* with other alphabet symbols c, d, e, . . . , z between the *ab* and the *ba*. The other solution would not even recognise *abba*.

Question 5 *Design a Finite Automaton to recognise any language that contains words with exactly one ab or with exactly one ba.*

A regular expression for the language in this case is

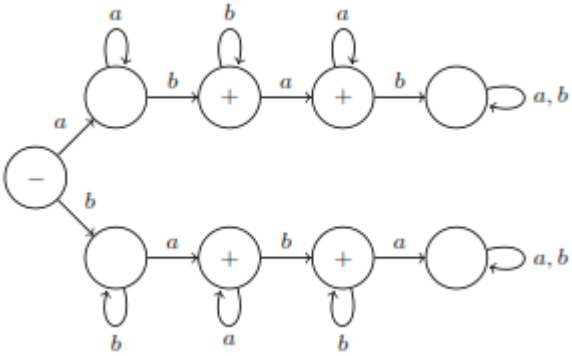
a*(ab)b* + b*(ba)a*.

An FA to recognise words in this language is shown below.



Two respondents managed the correct solution.

Two other respondents produced the solution below, which partially solved the problem but introduced an error because of the second accepting state on each branch.



Respondent 8 once again built a TG instead of an FA.

Respondent 5 built an FA that accepts words of the form *aba* and *bab* – words containing both the substrings *ba* and *ab*.

The other solutions are incorrect and display various degrees of confusion.

5. DISCUSSION

There are quite a few common errors in the solutions. These could relate to common misconceptions.

- Our expectation was that the respondents (when requested to design/build an FA) would build a Deterministic Finite Automaton (DFA) (because of how the textbook defines an FA). Many of the respondents designed NFAs. One interpretation of this is that the respondents knew that the edge would lead to a rejecting state and thus decided to omit that part of the FA. Another possible interpretation is that the respondents did not know what to do in such cases and so simply did nothing. This is something which should be tested in future work.
- In questions 2 and 3 a number of the solutions had extra states. These extra states seem to arise when the solution requires doing something when a word begins with an *a* and doing something else when the word begins with a *b*. The respondents know that there must be an edge leaving each state for each alphabet symbol and explicitly define these with each edge leading to a different state. This leads to a more complicated FA.

- Relating to the previous point: it may also indicate that there may be confusion about the concept of a start state: one respondent consistently added the additional state as described in the previous point, which could mean that the start state is seen as a special type of state: that the FA cannot remain in the start state and it has to move on.
- A common problem seems to be dealing with the remainder of a string after doing some processing that leads to an accepting state based on some initial substring.
- Respondent 8 seems to recognise that a TG is more powerful than an FA and so used a TG to solve two of the problems. Respondent 3 also commented that he/she would have preferred to design a TG rather than an FA for question 5.
- In question 5, two branches are required – one for the *ab* and one for the *ba*. If one has solved one branch then the other branch is the same except for swapping *a* and *b*. Some of the students did not seem to recognise this (e.g. respondent 10) and thus ended up with more complicated solutions.
- Additionally for question 5, as a special case, it appears as though FAs may be considered purely as a machine that consumes input on a symbol by symbol basis, without considering the word the machine recognises. As an example: does the word *aba* belong in the language (or does *bab* for that matter)? One of the respondents took the viewpoint of a machine that consumes: once the *ab* (or *ba*) was read, whatever followed (if not a unique *ba* or *ab*) was acceptable. This fails to recognise that the *aba* contains the substring *ab* and the substring *ba* which is not an allowed word based on the description of the language provided.
- One of the respondents provided a regular expression and verbal description of the FA that was attempted. When the FA was correct, the regular expression was also, however, when the FA was wrong, the regular expression did not match the FA (and in all but one case also did not describe the words in the language correctly). This could point to a misconception with matching FAs with regular expressions as supportive tools when drawing FAs.

6. FUTURE WORK

The study has illustrated some of the problems that students have in designing/building FAs to recognise various languages, but the study had a number of limitations which must be addressed in order to continue our attempt to understand student's difficulties in these exercises.

- We need to be explicit about the definitions we are using in posing the problems.
- We should be explicit about the alphabet that we expect the students to use.
- We need to more carefully assess the exercises before asking the students to complete them.

The biggest problem with this study was that we were not really able to probe why the respondents made the errors that they did. Future research should be done in a enviroment where the students are asked to explain why they are doing what they do at the time that they do it. To do this we will need to amend our ethics and permissions applications to allow this type of monitoring.

The development of a concept inventory, a standardized assessment tool that can be used in the analysis of students' concepts or misconceptions, and gain an understanding of where students are struggling [10, 20], is a long term goal of this research.

7. CONCLUSION

This research study was an initial attempt to understand the types of mistakes that students make when designing FAs to recognise words in given regular languages. Students in two Theoretical Computer Science modules were asked to complete five design exercises. The students' solutions were then compared to the "correct" solutions. The results show that most of the study group could do some of the easier exercises but that the number of incorrect solutions increased as the difficulty of the exercises increased. Common errors included treating FAs as nondeterministic, creating extra unnecessary states, difficulty in consuming the remainder of the input string after an accepting state has been reached and general confusion in dealing with more complex problems. In future research, we would like to be able to probe more deeply why the students make the errors that they do.

8. ACKNOWLEDGEMENTS

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APPENDIX

A. THE RESEARCH STUDY

A.1 Instructions to students

Dear student,

Dr Wynand van Staden, Mr Colin Pilkington and I (Prof Ian Sanders) are undertaking a research study in an attempt to determine and categorise students' misconceptions in designing Finite Automata to recognise given languages. This research will assist us in designing interventions which will be of benefit to future students studying COS2601 and COS3701. The research will also contribute to a larger project which looks at designing tools for use in COS2601 and COS3701.

For us to proceed with this research, we require your assistance. To be involved in the research you would need to do three things.

1. Complete the design exercises below (or as many of them as you can).

If you cannot complete any of the exercises we would still like to see your partial solutions or any ideas you have about how to tackle the problem. You can also comment on what aspects of the exercises you find particularly difficult or confusing. Any information that you can provide could be of use to us.

2. Read and sign the consent form on the next page.

3. Email the signed consent form with your solutions to sandeid@unisa.ac.za by the 15 of March 2015.

We will provide you with feedback on your solutions before the final examinations for the two modules. Note that once we have received your solutions and your signed consent form, we will remove any identifying information from the solutions and replace that with a study code number. Our analysis will be done on the anonymised solutions.

We will only report on the results of our study in terms of these anonymised solutions. In any reports or publications which ensue from this research we will only use the study code numbers and will not include any information which could identify you.

Regards

Prof I D Sanders

A.2 Study exercises

1. Design a Finite Automaton to recognise any language that has at least one *a*.

2. Design a Finite Automaton to recognise any language which starts with an *a*.

3. Design a Finite Automaton to recognise any language that contains words which have exactly one *b*.

4. Design a Finite Automaton to recognise any language that contains words with at least one *ab* and one *ba*. Note that the *ab* must appear before the *ba*.

5. Design a Finite Automaton to recognise any language that contains words with exactly one *ab* or with exactly one *ba*.

A.3 Informed consent form

Computing Students' Misconceptions in Designing Finite Automata

This study is being conducted by Ian Sanders, Colin Pilkington and Wynand van Staden who are undertaking research at the University of South Africa (UNISA). The aim of this project is to try to determine common misconceptions that computing students (second year and third year level) have in designing Finite Automata (FA).

Informed consent.

1. Voluntary participation: You are not required to submit the FA. You may also withdraw your participation at any time.

2. Confidentiality: The information produced by this study will be confidential and private. When reporting the results of the study we will not use your name or any information which could potentially identify you.

3. Benefits: We do not anticipate a direct benefit to you for completing the study. However, you will be providing valuable information that will inform decision making in the future.

Name and contact details of the researchers.

Ian Sanders, Colin Pilkington and Wynand van Staden

School of Computing

Unisa

011-471-2858

I (full name)_____,

Student number _____,

have read and understood this consent form, and willingly give permission that my responses to the FA design exercise be used as part of the study described above.

_____ _____

Signature Date

B. TABLE OF RESULTS

Table 1: Raw results for checking FA for errors

	Q1	Q2	Q3	Q4	Q5
1	Correct	Correct	Correct	Wrong Accepts words that begin with b which allows for $b*a$ which means it would accept a *ba* before any *ab*.	Correct
2	Correct	Wrong Solves the problem but not a DFA. Did not indicate what happens on a *b* in state 1.	Wrong Has not drawn a DFA. Did not indicate what happens on a *b* in the accepting state. Assumes will go to a rejecting state.	Wrong Has not drawn a DFA. What happens on a *b* in state 1?	Wrong Accepting state could allow repeats of *ab* or *ba* substring and FA does not check if these occur.
3	Correct More complicated than it needs to be. Has an extra state that it goes to if there is a *b* in initial state.	Correct	Correct Again an extra state for an *a* in initial state.	Wrong Could accept a *ba* before any *ab* by leaving initial state on a *b*. Actually accepts one or two *ab*s before any *ba*s.	Wrong *ab* path could accept a *ba*, *ba* path could accept an *ab*. Both by going to the second accepting state on the branch.
4	Correct	Correct	Correct	Wrong Could accept a *ba* before any *ab*. Because of *b* loop in initial state.	Wrong *ab* path could accept a *ba*, *ba* path could accept an *ab*. Both by going to the second accepting state on the branch.
5	Correct More complicated than it needs to be. Has an extra state that it goes to if there is a *b* in initial state.	Wrong Solves the problem but not actually a DFA, no loops on state reached by a *b* from initial state. Not a serious issue.	Correct Overly complicated. More states than necessary.	Wrong Could accept a *ba* before any *ab*. Because of *b* loop in initial state.	Wrong Very complicated. Could do with some probing.
6	Wrong Could accept a *b*. Should not leave initial state on a *b*.	Correct	Wrong No final state. Missing edge for b from state 2.	Wrong Needed to just consume extra characters at final state.	Wrong Cannot merge paths. Needs to consume characters.
7	Correct	Correct	Correct	Wrong Could accept a *ba* before any *ab*. Because of *b* loop in initial state.	Correct
8	Correct	Wrong Has not drawn a DFA. Did not indicate what happens on a *b* in state 1?	Correct	Wrong Designed a TG not an FA.	Wrong Designed a TG not an FA. TG is wrong.
9	Wrong Has not drawn a DFA. What happens on a *b* in state 1.	Wrong Two edges for *a* from initial state.	Wrong Overly complicated.	Wrong But almost correct. Does not deal with repeats of strings. Second attempt has similar problems but also accepts words with no *ab* or *ba*.	Wrong But almost correct. Does not deal with *aaaaabbbbbb* etc.
10	Correct	Wrong Not a DFA. What happens with a *b* in the initial state? State C not required and confuses the issue.	Wrong No idea.	Wrong At least recognises words cannot start with *b*. Accepts word with no *ba*.	Wrong One path *a*abb** correct. Other path wrong.

Precise Machine Translation of Computer Science Study Material

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ABSTRACT
Higher education in South Africa is, amongst others, characterised by student language diversity while the language of teaching and learning is mainly English. The University of South Africa has a language policy that is based on the notion of functional multilingualism, the implementation of which would benefit from software that provides fast, low-cost and easily accessible solutions to translating key concepts found in study material. We present a prototype translation system in the form of a mobile (Android) application for translating discrete mathematics definitions between English and Afrikaans. The main component of the system is a Grammatical Framework (GF) application grammar which produces syntactically and semantically accurate translations in a high precision domain. The extension of the system to other South African languages is outlined.

Categories and Subject Descriptors
I.2.7 [**Artificial Intelligence***]: Natural Language Processing*— machine translation, natural language generation, language resources

General Terms
Design, reliability

Keywords
Grammatical Framework, GF, machine translation, definitions, discrete mathematics

1. INTRODUCTION
Language diversity in South Africa is enshrined in the Constitution of the Republic of South Africa[1], which means that South Africa has eleven official languages. However, providing access to services, information and education, also higher education (HE), to South Africans in their own languages and thereby allowing them to participate in the 21st century knowledge economy, is a real challenge.

SACLA 2015, 02-03 July, Johannesburg, South Africa

[1]http://www.gov.za/documents/constitution-republic-south-africa-1996

Through the Use of Official Languages Act[2] of 2012 the public sector now has the obligation to offer its services in at least three official languages. This act has created a new wave of energy for, amongst others, multilingualism through language technology. In the higher education sector similar expectations have been expressed. In the White Paper on Post-School Education and Training[3] the development and use of the South African languages in academia and education is presented as a strategic challenge. However, in spite of these developments, the pressure of pragmatism and the scarceness of resources to address this complex problem have led to an HE sector in which the language of teaching and learning is still largely English, although the majority of HE institutions have initiatives to attempt to support language diversity. It is also generally acknowledged that this kind of multilingualism cannot be realised and sustained without the use of state of the art language technology.

The key issue that we address in this paper is the provision of advanced learner support in science and technology to students in HE in languages other than English, using language technology. In the theme of SACLA 2015, we are renewing English-based teaching and learning of Computer Science with new opportunities for access in other languages.

As an Open and Distance Learning university, the University of South Africa (Unisa) has a diverse body of students. Almost 80% of Unisa students studying in English are not mother-tongue speakers of English[4]. Unisa has a language policy that is based on the notion of functional multilingualism. In practice, for undergraduate students this means that glossaries of subject terminology must be provided in all the official languages of South Africa[5]. However, it is costly to translate by hand, for example, all the definitions of important concepts in the study material of some subject, since these definitions are not merely of subject terminology, but actually of key concepts in the material that must be translated by domain experts.

The functional multilingualism policy of Unisa could be supported by language technology in the form of software that provides a fast, low-cost and easily accessible solution to translating definitions of key concepts in study material. 70% of Unisa students have access to a smartphone, while 30% have

[2] http://www.gov.za/documents/use-official-languages-act
[3] http://www.che.ac.za/media_and_publications
[4] Barnes, G., Director: Information and Analysis, Unisa Institutional Development, personal communication
[5] http://www.unisa.ac.za/Default.asp?Cmd= ViewContent&ContentID=26800

access to a tablet[6]. Mobile device application platforms provide an easy way to make software available to a large number of people. It is also advantageous if a mobile device application can be used offline, as this avoids incurring data costs. A solution to providing translations of study content which runs offline on a mobile device would therefore be ideal.

In terms of translating study content, the obvious starting point would be the mathematical sciences, since definitions for concepts in these domains are precise and therefore easier to model computationally. Moreover, the challenge that the precision of this domain poses is the small margin for semantic error, and therefore any solution must guarantee *high quality semantic translation*.

In this paper, we present a precise machine translation system embedded in a prototype Android application. The domain is discrete mathematics, a typical course in a Computer Science degree. The application uses a Grammatical Framework (GF) grammar system to build definitions of key concepts and to provide syntactically and semantically accurate machine translations. Such a system would assist both in creating multilingual study material and in providing students with an interactive environment in which definitions could be authored and automatically translated. The typical use case would be that a student is able to use the application when studying to render the English definitions in his/her mother tongue. However, the powerful capabilities of GF provide a much wider use. The application was built for bilingual translation between Afrikaans and English, but the approach readily generalises to any other well-defined domain and any language, also the other official languages of South Africa. At the core of GF is a growing resource grammar library (RGL) currently containing resource grammars for 30 languages. The development of such grammars for the South African languages is an ongoing project, at present including Afrikaans and Tswana [8].

The paper is structured as follows: Section 2 briefly explains the research methodology. In section 3 we contextualise our research, both in terms of choice of domain and choice of translation paradigm. Section 4 explains our choice of the GF paradigm and how it provides an infrastructure for state of the art precise machine translation. In section 5 we apply the approach to the discrete mathematics domain through (i) an outline of the abstract syntax developed to model the semantics of the domain; (ii) an explanation of how the concrete syntaxes for the two languages were developed using the RGL API; and (iii) an evaluation of the resulting application grammar. Section 6 addresses the implementation of the solution as an Android application that uses the grammar to translate discrete mathematics definitions between English and Afrikaans. Section 7 concludes the paper and also provides some pointers to future work.

2. METHODOLOGY

The field of artificial intelligence (AI) attempts to understand, model and design intelligent systems. More specifically, research in natural language processing, a subfield of AI, is based on a small number of formalisms [6] of which the most common ones are state machines, rule systems, logic, probabilistic models and vector-space models. In this paper we consider a specific fragment of natural (*human*) *language* in the form of definitions in discrete mathematics, which we model using a *rule system* in the form of a suitable *formal grammar*. This model is then used to design and build a *machine translation system* that is shown to provide *grammatically and semantically sound translations* between the languages considered, based on an appropriate data set ("gold standard"). In short, modelling as research methodology [5], as often understood in AI research, forms the methodological basis of the work reported on in this article.

3. CONTEXTUALISATION

3.1 Content

The content selected for the purpose of this research is the detailed study guide for a first-year course in discrete mathematics. The choice of content was influenced by availability, but was mainly directed by the necessity of identifying a suitable subset of natural language for the scope of this research and the proof of concept presented. Suitability was judged against the following criteria: the corpus must be small and specific enough to restrict the kinds of sentences to be processed in order to present a workable solution, but large enough to ensure that the result is a significant improvement on the glossaries that are available to students.

After analysing the content of the detailed study guide for COS1501, it became apparent that the definitions present in the study guide constitute a suitable subset of natural language that meets the above criteria. The following are examples of sentences from the chosen subset:

1. For all positive integers *m*, *n* and *k*, addition and multiplication are associative.
2. There exists a positive integer, namely 1, which has the property that for every positive integer *m*, $m \times 1 = m$.
3. For all positive integers *m* and *n*, addition and multiplication are commutative.
4. A function $f: A \rightarrow B$ is injective if and only if whenever $f(\alpha_1) = f(\alpha_2)$, $\alpha_1 = \alpha_2$.

3.2 Choice of translation paradigm

There are several paradigms for machine translation [4] of which the two main categories are linguistics-based paradigms and data-based paradigms.

The strength of statistical machine translation, which is the most commonly used form of data-based approaches, lies in its flexibility: even when a perfect parse of the sentence in the source language is not possible, the system is able to return some sentence in the target language in every case, even if it is not entirely accurate. This is also, however, a weakness in exactly the kind of problem we are trying to solve. Definitions in fields like discrete mathematics rely on high accuracy, where a bad translation may even be worse than no translation, since it may expose the student to faulty information. For example, consider the two Afrikaans sentences below. The first is the result of applying Google Translate to sentence 1 above[7]. The $*$ indicates an incorrect translation. The second is the correct translation.

1. *Vir enige positiewe heelgetalle m, n en k, optelling en vermenigvuldiging is assosiatiewe.
2. Vir enige positiewe heelgetalle m, n en k, is optelling en vermenigvuldiging assosiatief.

[6] Barnes, G., Director: Information and Analysis, Unisa Institutional Development, personal communication

[7] https://translate.google.com, 2 April 2015

Two errors are present in the first sentence that significantly affect the perceived meaning of the Afrikaans. The verb “is” is in the wrong position, which obscures the relation between the prepositional phrase and the main clause. More importantly in this case, the adjective is in the attributive form instead of the predicative. Consequently, the morphologically and syntactically sound interpretation would be that “assosiatiewe” is a noun in the plural form, which in English would be associatives. This is clearly incorrect, since the English definition states that addition and multiplication have a certain property, not that they are members of some class, which is at best undefined and at worst non-existent in the study material.

Another weakness of statistical machine translation is the cost of adding a new language to a translation system. Statistical machine translation works with language-pairs, so adding new languages is exponentially expensive. This can be circumvented by using a single language as an interlingua, where each translation between two other languages actually consists of two translation steps via the interlingua. However, this introduces more opportunities for loss of precision.

Grammatical Framework (GF) is a linguistics-based paradigm for machine translation that addresses precisely these kinds of challenges. It is a functional programming language for building so-called application grammars. A GF application grammar is a system which consists of several domain specific grammar modules for different languages that are mapped to one central, domain specific abstract grammar module, which serves as a semantic interlingua. It also provides a so-called Resource Grammar Library (RGL) API, which hides syntactic and morphological information from the grammar developer. The RGL is currently implemented for 30 languages, including English and Afrikaans [11].

4. GRAMMATICAL FRAMEWORK

GF is a programming language for writing grammars. In terms of theoretical complexity, a GF grammar is equivalent to a Parallel Multiple Context-Free grammar, which is “an extension of context-free grammar for which the recognition problem is still solvable in polynomial time” [1]. Grammars written in order to describe natural languages are subject to being either incomplete (not including some grammatical expressions in the language) or overgenerating (including some expressions which are ungrammatical in the language). That is because, unlike formal languages which are defined by their grammar, natural languages exist independently of a systematic description. However, while the grammar of a natural language will never be a perfect description of the language, the symbolic approach of producing grammars for use in natural language processing can still be useful. This is especially true for smaller, well-defined domains, where only a subset of natural language is used [9], and this is typically the case in scientific domains where accuracy and unambiguity is of the essence.

4.1 Grammars in GF

A GF grammar consists of two kinds of components, a single abstract syntax and one or more concrete syntaxes. According to [9], the \abstract syntax is a tree-like representation that captures the semantically relevant structure of language. The concrete syntax relates the tree structure to linear string representations.” For example, suppose we want to express integer addition. In the various concrete syntaxes, we may require different linearisations for adding the integers 2 and 3: “the sum of 2 and 3”, “2 plus 3” and “2 + 3”. In order to achieve this, the abstract syntax would define the following function:

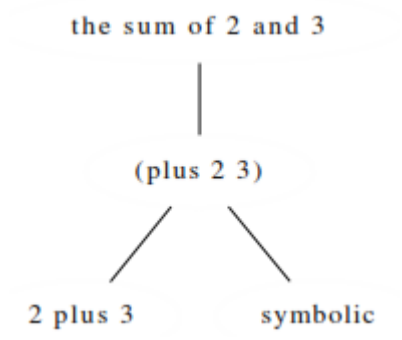

Figure 1: Abstract syntax as interlingua

```
fun IntAdd : Int -> Int -> Exp
```

This means that the function IntAdd takes two parameters of type Int and returns a value of type Exp. The concrete syntaxes would have the following rules for linearisation of the plus function:

```
--Eng
lin IntAdd x y = "the sum of" ++ x ++ "and"
++ y
--Afr
lin IntAdd x y = x ++ "plus" ++ y
--Java
lin IntAdd x y = x ++ "+" ++ y
```

`Int` and `Exp` are categories (`cats`) defined in the abstract syntax. They are represented by strings in the concrete syntax, so we say that their linearisation types (`lincats`) are of type `Str`.

A powerful feature of GF is that the abstract syntax is independent of features like word order and inflection. Therefore, an abstract syntax could serve as interlingua for widely different languages (see figure 1). It should also be noted that GF grammars are reversible, that is, the same grammar is used to parse linear input and to generate it [9].

The original intention of GF was to write application grammars. These are usually multilingual grammars, meant for use in a specific domain for a specific purpose, such as mathematics exercises, tourist phrasebooks etc. [12, 3, 10]. The abstract syntax serves as a semantic model of the domain, and the concrete syntaxes relate the concepts in the abstract syntax to natural language linearisations for each language. This guarantees translation equivalence, since no syntactic assumptions are made outside of the language specific concrete syntaxes. The abstract syntax in this case is known as a semantic grammar [9]. This also means that the cost of adding new languages is linear, since it involves only the addition of a single concrete syntax module for the new language.

GF also supports syntactic grammars, which have the more modest goal of relating concrete linearisations of general syntactic structures, such as sentence creation from noun phrases and verb phrases. The concrete syntaxes are known as resource grammars and are collected in the GF RGL, while the functions implemented in them are made available via an API. This means

that new grammars can build on previous ones [9]. For example, the RGL API contains the following function for creating common nouns from adjectival phrases and common nouns:

```
fun mkCN : AP -> CN -> CN
```

Each concrete syntax grammar can then define a linearisation function for forming a common noun from an adjectival phrase and a common noun. The goal of the RGL is not to achieve semantic translation equivalence, but to serve as a kind of standard library for linguistic functions. Typically, the syntactic resource grammars are written by linguists, while application grammars that make use of the API are written by domain specialists [9]. This is an important aspect of GF and means that the syntactic structure of any given language needs to be modelled only once and will then continue to exist as a GF resource grammar for that language. Any future applications will never have to redo the low-level linguistics and can focus on modelling the semantics of any chosen new domain. So, since resource grammars for English and Afrikaans already exist, the focus in subsequent sections is on modelling the chosen application domain.

4.2 Application grammars and the resource grammar library API

In this section we show some minimal examples of GF grammars in order to give a more detailed view of the way GF handles linguistic features in a language and how the RGL facilitates in hiding these details from the application grammar developer. We present some GF code, which we have kept as simple and self-explanatory as possible. Since it is beyond the scope of this paper to include a comprehensive introduction to the GF programming language, the interested reader is referred to [9].

Suppose we have a miniature semantic grammar for the domain of discrete mathematics definitions as shown in figure 2, where the categories `Statement`, `Operation` and `Property` are defined, along with functions for constructing these categories. In English, an `opStatement` would be represented by sentences such as "Multiplication is commutative" or "Multiplication and addition are distributive". We might therefore develop a concrete syntax for English as shown in figure 3. Notice that each category is assigned a linearisation type, which in this case is `Str` for all three. However, this grammar fails to render "Multiplication and addition are distributive" correctly, because `opStatement` is linearised as containing the string "is". That is, the function does not correctly address the question of number in noun phrases referring to multiple operations. The concrete syntax shown in figure 4 amends the situation. In it we change the linearisation type for the category `Operation` to include a field **n** of type `Number` for storing either `Sg` or `Pl`, which is then used in a case statement to produce "is" or "are" as required.

This approach, however, leaves important linguistic work up to the author of the application grammar, who might not be an expert linguist. A significantly cleaner solution is simply to use the RGL API. Such a concrete syntax is shown in figure 5. Here, `Utt`, `NP`, `mkCN` etc., are all categories or functions defined in the API, and `SyntaxEng` and `ParadigmsEng` are modules from the English resource grammar that are used to access their linearisations. Instead of constructing the linearisation types directly, functions such as `mkNP` are used instead. Now, writing a similar concrete syntax for an additional language only requires choosing the correct syntactic structures from the new language's resource grammar in such a way as to achieve translation equivalence. This shows that the availability of a resource grammar for a specific language greatly simplifies the process of developing a concrete syntax in that language for a given application grammar system.

```
abstract Mini = {
flags startcat = Statement;
cat
 Statement; Operation; Property;
fun
 opStatement: Operation -> Property -> Statement;
 andOper: Operation -> Operation -> Operation;
 multiplication: Operation;
 addition: Operation;
 associative: Property;
 commutative: Property; }
```

Figure 2: Abstract syntax for a mini semantic grammar

```
concrete MiniOne of Mini = {
lincat
  Statement = Str ; Operation = Str ;
  Property = Str  ;
lin
  opStatement operation property
   = operation ++ "is" ++ property ;
  andOper op1 op2 = op1 ++ "and" ++ op2 ;
  multiplication = "multiplication" ;
  addition = "addition" ;
  associative = "associative" ;
  commutative = "commutative" ; }
```

Figure 3: A first attempt at a concrete syntax

4.3 Previous related work

GF is well-suited for building translation systems in precise domains, with examples including the various application grammars developed as part of the MOLTO project, including a tourist phrase book, as well as accurate translation of domain specific content such as museum data and patents [10]. Other projects with a similar focus as in this paper have also been done.

```
concrete MiniThr of Mini = open ParadigmsEng,
                                SyntaxEng in {
lincat
  Statement = Utt ; Operation = NP ;
  Property = NP ;
lin
  opStatement operation property
   = mkUtt (mkS (mkCl operation property)) ;
  andOper op1 op2 = mkNP and_Conj op1 op2 ;
  multiplication
   = mkNP (mkCN (mkN "multiplication"));
  addition = mkNP (mkCN (mkN "addition"));
  associative = mkNP (mkCN (mkN "associative"));
  commutative = mkNP (mkCN (mkN "commutative"));}
```

Figure 5: A third attempt at a concrete syntax

```
concrete MiniTwo of Mini = {
lincat
  Statement = {s: Str} ;
  Operation = {s: Str; n: Number} ;
  Property = {s: Str} ;
lin
  opStatement operation property = {s = case operation.n of
                                        { Sg => operation.s ++ "is" ++ property.s;
                                          Pl => operation.s ++ "are" ++ property.s }} ;
  andOper op1 op2 = {s = op1.s ++ "and" ++ op2.s ; n = Pl} ;
  multiplication = {s = "multiplication"; n = Sg } ;
  addition = {s = "addition"; n = Sg } ;
  associative = {s = "associative"} ;
  commutative = {s = "commutative"} ;
param
  Number = Sg | Pl ; }
```

Figure 4: A second attempt at a concrete syntax

The most closely related of these is the WebALT project, of which the core deliverable is a grammar for mathematics for several European languages [2]. A second relevant deliverable of the project is the TextMathEditor, which is a graphical interface for "authoring mathematical text conforming to the WebALT grammars" [2]. The project is conceptualised in layers, with a mathematical core and a natural language "shell". The system extends the OpenMath standard, so that the WebALT grammar allows mathematics problems to be authored and rendered in several European languages. The OpenMath standard "provides an unambiguous language-independent representation of the exercise problem" [7].

The WebALT project, however, differs significantly from this work. While WebALT focuses on rendering mathematical expressions in natural language, we focus on the surrounding natural language segments in definitions. Our assumption is that complex mathematical expressions, like $R \subseteq A \times A$, are not translated, but simply copied, and that the semantics of the surrounding natural language as it appears in the study material corpus for discrete mathematics must be translated accurately.

5. A GRAMMAR FOR DEFINITIONS IN DISCRETE MATHEMATICS

We now turn to the development of a GF application grammar for definitions of discrete mathematics concepts. The central component of such a grammar system is the abstract syntax, which is in reality a model for the semantics of the domain. The process of developing a suitable model of the domain consists therefore of identifying the semantic categories of the domain and determining how statements about them are constructed. Ultimately, of course, implementing the model as a grammar system must lead to correct linearisations of the concepts and statements in the relevant natural languages. Consequently, we first describe the analysis of the domain in order to determine the required output for the grammar, and then present a discussion of the most prominent features of the application grammar.

5.1 Content analysis

Our first step was to analyse the study material content in order to create a gold standard according to which the output of the grammar could be evaluated. Grammar development for such a restricted domain is an iterative process, where the gold standard acts as a specification, and the output of the grammar is continually compared to it until it produces the required output.

Therefore, we first developed a corpus of parallel sentences to serve as a specification for the grammar. This was done by extracting a set of definitions that fully represents the syntactic variety found in the English study material and translating them to Afrikaans by hand. However, we found that the language used in the study material was somewhat varied, with the equivalent notions being expressed in different ways. To keep the grammar to a manageable size and to avoid overgeneration, the definitions were paraphrased slightly to be consistent, before translating them to Afrikaans.

Here are some of the sentences as they originally appear in the study material, followed by the paraphrase (a), the Google translation of it into Afrikaans (b)[8], and finally the correct Afrikaans translation (c).

1. For all positive integers m and n, addition and multiplication are commutative.
   (a) For all positive integers m and n, addition and multiplication are commutative
   (b) *Vir alle positiewe heelgetalle m en n, optelling en vermenigvuldiging is kommutatiewe
   (c) Vir alle positiewe heelgetalle m en n is optelling en vermenigvuldiging kommutatief

2. There exists a positive integer, namely 1, which has the property that for every positive integer m, $m \times 1 = m$.
   (a) There is a positive integer 1 so that for any positive integer m , m×1 = m.
   (b) Daar is 'n positiewe heelgetal 1 sodat vir enige positiewe heelgetal m, m×1 = m.
   (c) Daar is 'n positiewe heelgetal 1 sodat vir enige positiewe heelgetal m, m×1 = m.

[8] https://translate.google.com, 2 April 2015

3. A relation $R \subseteq A \times A$ is transitive iff R has the property that for all $x, y, z \in A$, whenever $(x, y) \in R$ and $(y, z) \in R$, then $(x, z) \in R$.
   (a) A relation $R \subseteq A \times A$ is transitive if and only if for all elements x, y and z in A whenever $(x, y) \in R$ and $(y, z) \in R$ then (x, z) $\in R$.
   (b) *A verhouding $R \subseteq A \times A$ is oorganklike as en slegs as vir al die elemente x, y en z in A wanneer $(x, y) \in R$ en $(y, z) \in R$ dan $(x, z) \in R$.
   (c) 'n Relasie $R \subseteq A \times A$ is transitief as en slegs as vir alle elemente x, y en z wanneer $(x, y) \in R$ en $(y, z) \in R$ dan $(x, z) \in R$

4. A relation R on A (also written as $R \subseteq A \times A$) is called reflexive on A iff for every $x \in A$, we have $(x, x) \in R$.
   (a) A relation R on A is reflexive if and only if for all integers x in A , $(x, x) \in R$
   (b) *A verhouding R op 'n refleksief as en slegs as vir alle heelgetalle x in A, $(x, x) \in R$
   (c) 'n Relasie R op A is refleksief as en slegs as vir alle heelgetalle x in A , $(x, x) \in R$

Note that sentence 2 is the only case where the Google translation corresponds to the correct Afrikaans translation. The errors for the other sentences include word order, especially relating to the position of the verb, morphological errors as well as incorrect terminology, and in sentence 4, the symbol A is translated as the indefinite article, while the main verb is completely absent. These are serious errors, and in section 4.3 we conclude that the GF application grammar avoids them all.

5.2 Category types and functions

The application grammar's abstract syntax models the semantics of the domain. It consists of a list of category types (`cats`) and functions (`funs`) for constructing the category types. The first step in developing the abstract syntax is to determine which category types are needed to accurately model the domain. The first column in table 1 shows the chosen category types for our application grammar, with an example of each given in the second column.

In each concrete syntax, the categories are made to correspond to linearisation types (`lincats`), which may be drawn from the RGL API. Using the API ensures that the English and Afrikaans concrete grammars are virtually identical in that they assign the same linearisation types in their concrete grammars to each category type in the abstract grammar, as shown in the final column of table 1. For example, in both languages, phrases establishing the scope of a statement, modelled in our grammar by the category Scope, are expressed as adverbial phrases, and hence the linearisation type Adv from the RGL is used. This is a consequence of the syntactic similarity of Afrikaans and English, but it is not a requirement in order to develop semantically accurate application grammars. The last column of table 1 shows which RGL linearisation types were assigned to each category.

As each category type in the abstract syntax has a corresponding linearisation type in each concrete syntax, so each function in the abstract syntax has a corresponding linearisation function (lin) in each concrete syntax. The linearisation function defines how the linearisation types of the parameters combine to form the linearisation type of the return category type. Functions for constructing category types may be divided into syntactic functions and lexical functions. Lexical functions take no parameters, and are used to construct the terminal nodes of the abstract parse tree. Syntactic functions combine category types to form category types that occur higher up in the parse tree.

Table 1: Grammar categories

cat	Example	lincat
FStatement	x is an integer	Utt
Statement	x is an integer for	S
Scope	any integer x	Adv
OperationList	addition and division	NP
Operation	multiplication	CN
Description	injective and surjective	AP
Property	injective	A
Subject	integer y	CN
Symbol	z	CN
Set	A	CN
SymbolList	integers x , y and z	ListNP
MathType	integer	CN
MathExpression	x ≤ y	Symb

Syntactic functions

For example, the syntactic function `quantStatement` takes parameters of type `Scope` and `Statement` and returns another `Statement` representing a quantified statement. This reflects the semantics of a sentence such as "For all nonzero integers x and y, x/y is rational". The category `Scope` represents the notion of quantification over some entity, in this case universal quantification over "non-zero integers x and y", and it is expressed as an adverbial phrase (`Adv`) in English and Afrikaans. The `Statement` that is passed as a parameter represents the notion that *x*/*y* is rational, and this is expressed as a sentence (`S`) in both languages. While the abstract syntax tells us that `quantStatement` combines a `Scope` instance and a `Statement` instance to form a new `Statement`, the concrete syntaxes tell us that in English and Afrikaans this is achieved by combining an `Adv` instance with an S instance to form a new `S`. Table 2 gives a comparison of the abstract and concrete syntaxes, and also shows which categories and function from the API is used. The first column contains the snippets of code in the abstract syntax of the application grammar which define the relevant categories (cats) and function (lin). The second column shows the corresponding concrete syntax code for the application grammar, while the third column shows the categories and function made available via the API to be used in the concrete syntax. Finally, the fourth column gives an indication of what each code snippet represents in English. A full abstract syntax tree is given in figure 6 and the corresponding English concrete tree are given in figure 7.

In our application grammar, the functions for forming statements can be divided into general statements, including quantified statements and statements about properties of entities, and conditional statements. Table 3 gives some examples of functions for statements included in the grammar, showing the definitions of both the fun in the abstract syntax and the lin in the concrete syntax.

There are also functions for constructing `Descriptions`, `Symbols`, `Subjects` etc. Some examples are shown in table 4 with both their `funs` and `lins`.

Table 2: Comparison of abstract and concrete syntaxes for function quantStatement

Abstract syntax	Concrete syntax	RGL API	English
cat Scope	lincat Scope = Adv	Adv = {...}	for all non-zero integers *x* and y
cat Statement	lincat Statement = S	S = {...}	*x / y* is rational
fun quantStatement: Scope -> Statement -> Statement	lin quantStatement: scope statement = mkS scope statement	mkS : Adv -> S -> S	for all non-zero integers *x* and *y*, *x / y* is rational

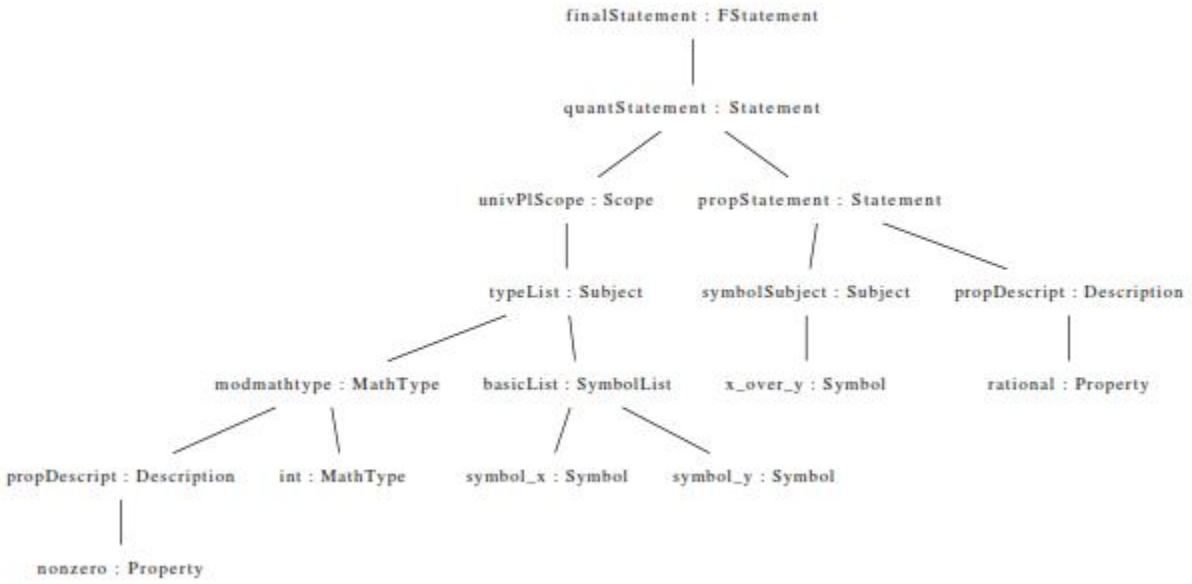

Figure 6: Abstract tree: for all non-zero integers *x* and *y*, *x / y* is rational

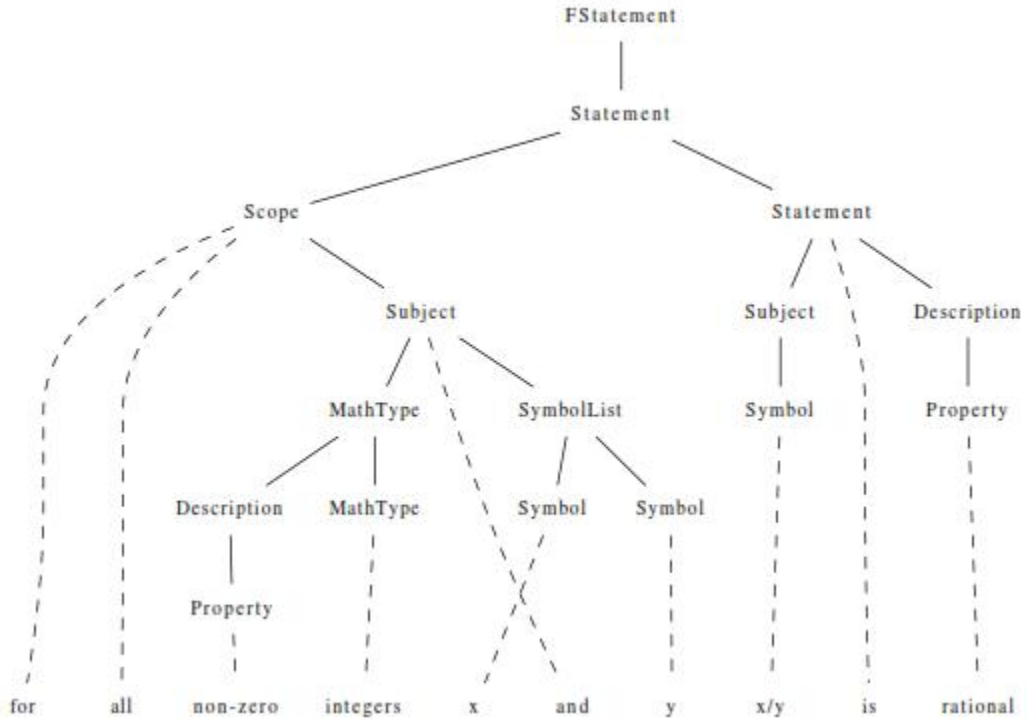

Figure 7: English concrete tree

Table 3: Examples of functions for constructing statements

Linearisation	Function and linearisation function
x is positive	propStatement : Subject -> Description -> Statement propStatement subj descr = mkS (mkCl (mkNP subj) descr)
for any positive integer x, $x > 0$	quantStatement : Scope -> Statement ->Statement quantStatement scope statement = mkS scope statement
if $x > 0$ then x is positive	ifStatement : Statement -> Statement -> Statement ifStatement s1 s2 = mkS if_Subj s1 s2
x is positive and y is negative	andStatement : Statement -> Statement -> Statement andStatement s1 s2 = mkS and_Conj s1 s2

Table 4: Examples of functions for constructing other entities

Linearisation	Function and linearisation function
for some x	existSgScope : Subject -> Scope existSgScope subj = mkAdv for_Prep (mkNP someSg_Det subj)
injective and surjective	andDescript : Description -> Description -> Description andDescript descr1 descr2 = mkAP and_Conj (mkListAP descr1 descr2)
x in A	inSymbol : Symbol -> Symbol -> Symbol inSymbol symb set = mkCN symb (mkAdv in_Prep (mkNP set))
addition and multiplication	andOperation : Operation -> Operation -> OperationList andOperation op1 op2 = mkNP and_Conj (mkListNP (mkNP op1) (mkNP op2))
integers x and y	typeSubject : MathType -> Subject -> Subject typeSubject mathtype subj = mkCN mathtype (mkNP subj)

Lexical functions

The functions for constructing the lexicon provide the terminal nodes of the abstract tree structure, and typically include functions for expressing elements such as *x*, *R* or $A \subseteq B$. Two challenges present themselves. The first is the sheer magnitude of possible symbols, including all Latin alphabet characters, Greek symbols, integers and other numbers, etc. The second is that constructing meaningful mathematical expressions from such symbols requires a dedicated grammar of its own. Our focus is not on translating the mathematical expressions and symbols, but the surrounding text. We therefore provide in the lexicon a few convenience functions for the symbols that are most often used in the domain, namely *x*, *y*, *z*, *A*, *B*, *C* and *R*. We also include functions for constructing placeholder items, namely [symb1], [symb2] and [symb3] for symbols, [func1], [func2] [func3] for functions and [expr1], [expr2] and [expr3] for mathematical expressions. It therefore falls to the software application using the grammar to allow the user to assign meaningful content to these grammar entities.

5.3 Grammar evaluation

The grammar described in section 5.2 produces output which corresponds exactly to the gold standard specification. This is not surprising, as it was developed expressly with this specification in mind. As such, it already achieves the desired result, which is accurate Afrikaans translations for the English study material. Specifically, word order, especially the position of the verb, is rendered correctly, and the correct morphological forms of adjectives are used. Naturally, terminology is also correctly translated.

However, the grammar is not restricted only to the definitions in the gold standard. It is a model of the semantics of the domain in the sense that meaningful sentences relating to the domain may be constructed with it, but new and unseen sentences may also be constructed. These sentences may be factually inaccurate, but the grammar is capable of producing translation equivalents of them nonetheless. It is possible with GF to generate random sentences from the grammar. We therefore created a corpus of 100 randomly generated abstract trees and linearised them in both English and Afrikaans. The corpus contained English "definitions" such as "if there is a z so that [expr1] then there is a z so that [expr2]" and "multiplication and subtraction are empty and whenever [expr2] then [expr1]". This new parallel corpus of random sentences was checked by hand, and it was determined that in each case, the English and Afrikaans sentences were translation equivalents. This means that the grammar is capable of successfully translating even unseen "definitions" in the domain of discrete mathematics. We discuss the implications of this and resulting possibilities in section 7.

6. ANDROID APPLICATION

Having developed a grammar that accurately translates definitions in the domain of discrete mathematics between English and Afrikaans, we now show how it can be used in an Android application. The GF grammar can be compiled into a PGF (Portable Grammar Format) object. A C-runtime system for GF exists that is capable of interacting with PGF objects, and along with JNI bindings it can be used in Android applications. The grammar is therefore embedded in the application, which means that the translation system is available to students offline.

The most important functionality provided by the runtime system is that of parsing input into abstract trees and linearising such trees into natural language strings. Translation consists of parsing a string using one concrete syntax, and linearising the resulting tree using a different concrete syntax. Our application exploits another very useful feature of the runtime system, which is its ability to provide so-called continuations. That is, given a (possibly empty) string of tokens, it can provide all the possible tokens, or continuations, that are allowed by the grammar. This is often referred to as "predictive editing", and it allows the user to construct only such strings as can be successfully parsed and translated.

The application presents the user with an interface for constructing discrete mathematics definitions in either English or Afrikaans using continuations and then translating them. Figure 8 shows the state of the application before any tokens have been chosen, while figure 9 shows how the options for continuations change as the definition is constructed. Three buttons are available for allowing the user to delete a single token (←), to delete all the tokens ( ) or to translate the definition ( ). It is also possible to choose the source language and target language from a drop down list (in this case the options are English and Afrikaans, but this may be extended), as well as to switch the source and target languages ( ).

Recall also that the grammar we developed leaves some work to be done by the software application that uses it. The user must be able to assign meaningful content to the lexical items that are rendered by the grammar as [symb1] and [expr3] etc. This is done in the Android application by supplying a dialogue box where the user may create a custom string by which the token is replaced. Initially, the placeholders appear in the tokens list as they exist in the grammar, that is, as [func1] and [expr1] etc. Once the user has clicked on one of the placeholders, the dialogue box prompts the user to enter the string, which is then associated with that lexical item for the remainder of the process of parsing the current definition (see figure 10). Notice that some buttons for inserting mathematical symbols is included in the dialogue box, since these symbols are not typically included in Android keyboards.

Finally, the completed definition must be translated. Figure 11 shows the completed English definition and its Afrikaans translation.

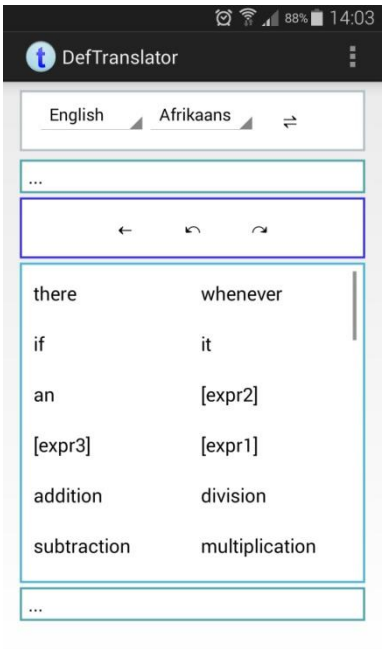

Figure 8: Possible start tokens

7. CONCLUSION

Our goal was to develop a precise machine translation system for definitions taken from study material for discrete mathematics that could be used offline on a mobile device.

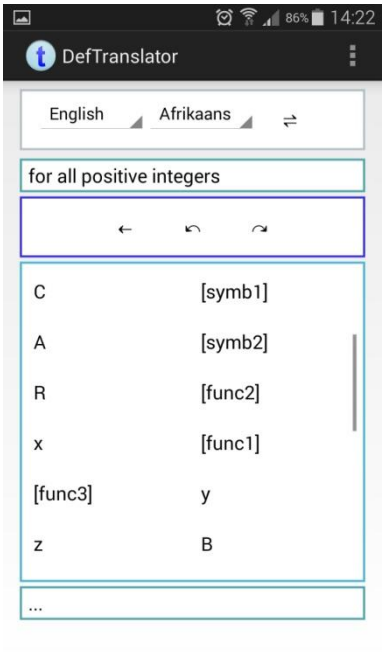

Figure 9: Using continuations to construct a definition

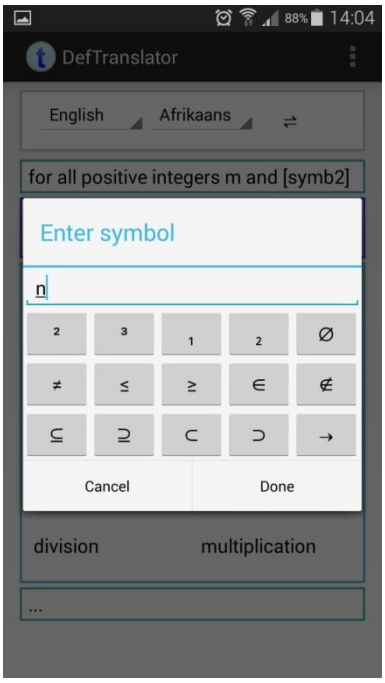

Figure 10: Dialogue for creating custom expressions

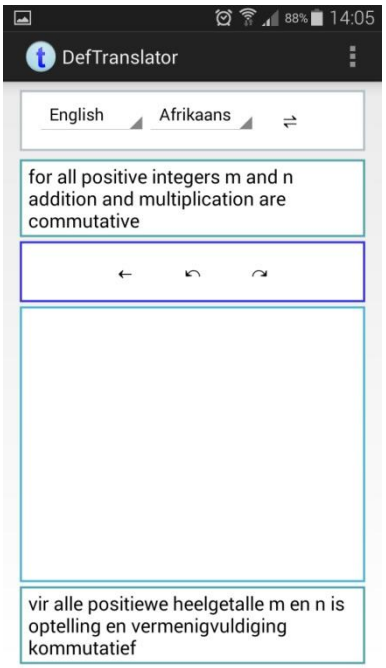

Figure 11: The completed English definition and its Afrikaans translation

Section 5 gave an overview of the translation system, namely the GF application grammar, and section 6 presented an Android application that provides offline translation between Afrikaans and English. It does this by guiding the user to construct definitions that can be successfully parsed and translated by the grammar. We therefore have an effective prototype solution for the use case of a student, using the application while studying, to translate English content into his/her mother tongue.

As mentioned in the evaluation of the grammar, however, the translation system allows for accurate translation between new and unseen definitions as well. This means, additionally, that students may participate in a creative and interactive process to create new content in their mother tongue and translate it into English. In a first year course on discrete mathematics, the formulation of new definitions may not be a primary goal, but it nevertheless provides students with a tool for experimenting with concepts in their own language and being able to express these concepts accurately in English. The ability to do this becomes much more relevant if the domain is extended beyond definitions to include proofs as well. Students are regularly required to construct their own proofs, and the assistance of a precise translation system that reduces the cognitive load by allowing them to formulate thoughts in their mother tongue may certainly be beneficial.

Future work may include the extension of the domain to proofs in the domain of discrete mathematics, or it may involve attempting to develop an application grammar that accurately models definitions in a different domain.

However, a more pressing challenge is extending the current system to include more South African languages. We showed in section 4 how the availability of a resource grammar for a language greatly simplifies the development of concrete syntax modules for that language. In fact, for the case of English and Afrikaans, their being so syntactically similar meant that developing a concrete syntax for Afrikaans from the English consisted of nothing more than copying the code and changing the language extension. The other official South African languages may differ more significantly from English and Afrikaans, but they share many common features between themselves. If resource grammars were available for them, the extension of application grammars to all South African languages would be similarly simplified.

In conclusion, we have shown that it is indeed possible to produce a system that provides precise machine translation of computer science study material, and that such a system can be embedded in a mobile device application. This is an important step towards providing advanced learner support in computer science in languages other than English. The development of resource grammars for the other South African languages, a project currently under way, will open up important opportunities for language diversity in HE.

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Pair Programming in the Introductory Programming Class

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ABSTRACT

This paper reports on a mixed methods study that investigated the experiences of South African students with pair programming in an introductory programming course. The results showed that the majority of students prefer pair programming over solo programming, but the female students and black students are even more positive about the pair programming experience. However, a rather large group of white male students are very negative about the pair programming experience. Students reported on a number of advantages with the use of pair programming and very little difficulties were reported. Pair programming is beneficial for the majority of students in an introductory programming class and the approach may also lead to more female and black students being attracted to and retained in programming classes.

Categories and Subject Descriptors

K.3.1 [**Computer Uses in Education**]: Collaborative learning; K.3.2 [**Computer and Information Science Education**]: Computer science education

General Terms

Human Factors

Keywords

Pair programming, Computer, Programming, Computer Science Education, Collaborative learning

1. INTRODUCTION

South Africa has a shortage of software developers, but this skills shortage is actually a worldwide phenomenon [6; 14]. Educators are acutely aware of the decline in enrolment in computing fields that has occurred since 2000 with the field continuing to lose the participation and interest of a broad stratum of students [18; 11]. Another alarming phenomenon is the low retention rate of students, with students either dropping the course, or not completing the course, or ultimately failing the course [19; 29].

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In view of the discriminatory Apartheid past of South Africa, the Employment Equity Act [25] requires from companies to ensure through affirmative action that designated groups (black people, women and people with disabilities) have equal opportunities in the workplace. This is a double concern for ICT companies in South Africa since there is a shortage of black ICT professionals [5] and on top of that, the shortage of women in the computing disciplines is a reality in South Africa as much as it is a worldwide phenomenon [14].

The main objectives of an introductory programming course are firstly, to excite learners about computing and programming and secondly, to better understand basic programming principles [3]. Hazzan [10] believes that in order to generate greater excitement among potential CS students, we should highlight the fact that human aspects, in general, and teamwork, in particular, are at the heart of the actual work of the discipline's graduates. IT educators must create a collaborative, socially-engaging environment with clearly defined boundaries that appeals to the current generation of students and that paints a more realistic picture of the collaborative nature of professional IT careers [7; 32].

Williams and Upchurch [33] suggested that pair programming, where two programmers work at one computer on the same programming task, shows several promising properties for educational purposes. A number of research studies on pair programming in tertiary institutions have since been done, but pair programming has mostly been explored in classes in developed countries. No mixed methods study in a developing country could be found that studied students' experiences with pair programming. In the light of the shortage of software developers the present study investigated pair programming in an introductory programming class in South Africa. The research questions and sub-questions were:

- What are students' preferences regarding pair programming?
  - What are the preferences of the less represented people (black people and women) in programming courses regarding pair programming?
- What are students' experiences with pair programming?

1.1 Introductory programming classes

An introductory IT course has many objectives. One of the objectives of such a course is to excite learners about computing and programming. A second objective is that students better understand basic programming principles. For some learners, the

course may be the only formal exposure they have to IT. For others, the introductory IT course creates their first impression of programming and is a deciding factor in respect of whether they will continue in computing [3].

Traditionally, IT courses started with programming, but it took learners several weeks before they could create even a simple program. Learners would work individually and quickly become frustrated with the syntax requirements and multiple iterations of work required before any results could be observed [27]. The abstract nature of programming concepts, application of programming concept knowledge and the correct mental model of program code execution are a few of the factors that contribute to the difficulty faced by novice programmers. Students who struggle to understand programming concepts become frustrated and are more likely to change to another "easier" subject [17].

1.2 Pair programming in the IT class

Traditional introductory programming courses generally require that learners work individually on their programming assignments. This approach teaches learners that software development is an individual activity, potentially giving learners the mistaken impression that programming is an isolating and lonely career. Pair programming seems to have a positive effect in general on computer science students at universities [15; 28; 30].

An emerging software development methodology, Extreme Programming (XP) [1], has popularised pair programming. With this style of programming, two programmers work side by side at one computer, continuously collaborating on the same design, algorithm, code, or test. One of the pair, called the driver, types at the computer or writes down a design [35]. The partner, called the navigator, continuously and actively examines the work of the driver – watching for errors, thinking of alternatives, looking up resources, and considering strategic implications of the work at hand. The navigator identifies tactical and strategic deficiencies in the work. The driver and navigator can brainstorm at any time. Periodically, it is also very important for the driver and the navigator to switch roles [31].

The following advantages of pair programming were found by researchers in a tertiary education context:

- Students working in pairs enjoy programming more than solo programmers and they are happier and less frustrated [19; 20; 33; 8; 3; 7; 23].
- Students in paired labs have a positive attitude towards collaborative programming settings and they show positive reactions to working with a partner using the pair-programming paradigm [16].
- Students who pair are more confident in their programming solutions and are more satisfied with the programming process than students who work alone [19; 20; 3; 12; 22; 23].
- There is a great reduction in defect count because pair programming's shoulder-to-shoulder technique serves as a continual design-and-code-review, leading to the most efficient defect removal rates [33; 8].
- It appears that as a result of pair programming, students who might otherwise have dropped the course, complete the course, and consequently pass it. It also contributes to greater persistence in computer science-related subjects and encourages students to pursue computing careers [19; 20; 4].
- Pair programming is an effective pedagogical tool for teaching introductory programming [19; 35]. Students who pair in the introductory programming course are more likely to attempt the subsequent programming class, and more likely to pass it, than those who initially learn to program independently [20].
- Students working in pairs achieve significantly higher grades than those working alone [19; 22].
- Students observed that they were more productive when working collaboratively, taking less time and producing a higher quality product [33; 8; 2; 13].
- Pair programming makes programming more of a group effort than a solitary piece and it is useful in terms of learning how to work with other people, to communicate with another person effectively and how to coexist with other people [24].
- Pair programmers learn a lot from each other [33; 8; 21] and their partner serves as a learning resource [24].

The following advantages of pair programming, specifically focused on females, were discovered by researchers:

- Female students working in pairs enjoy the programming process [29]; the enjoyment comes from the usefulness of the program and teamwork [15].
- Typically, female students in programming classes are less confident in their abilities than male students. This lack of confidence leads female computer science students to doubt their capabilities, question whether they belong, and frequently leads them to select other courses. The gender gap in confidence is significantly reduced when the students program in pairs [29].
- Female students also are less likely than males to persist in computing-related majors. Pair programming increases the retention rate in computing-related study fields [19; 28; 30].
- The collaborative nature of pair programming teaches female students that programming is not the competitive, socially isolating activity that they imagined [28].
- Pair programming helps female students work more efficiently in programming tasks [15].
- Female students working in pairs achieve significantly higher grades than those working alone [29].

From the above-mentioned advantages it is clear that pair programming can be beneficial to students because it might address factors that potentially limit their participation in the computing

field. Research on South African students' experiences could provide valuable information to attract and retain more students to the computing field.

2. METHODOLOGY/DATA COLLECTION

In this section the research design, the demographics of the participants, as well as the data collection and analysis are discussed.

2.1 Research Design

A mixed methods approach was used to conduct the research. Tashakkori and Creswell [26] describe mixed methods as: "Research in which the investigator collects and analyses data, integrates the findings, and draws inferences using qualitative and quantitative approaches or methods in a single study or programme of inquiry". Mixed methods research will often provide the most informative, complete, balanced, and useful research results [27]. Creswell and Clark [9] suggested four major types of mixed methods design: (1) triangulation; (2) embedded; (3) explanatory; and (4) exploratory. In this study the type of mixed methods research was (3) explanatory, as the objective of the qualitative investigation was to supplement the quantitative investigation and to better understand and explain the observations of the quantitative investigation.

The participants were first-year students in an introductory C# programming course called Graphical Interface Programming. All the students were trained by their lecturer in the use of pair programming and they were informed that pair programming was to be used for all programming assignments during the semester. Students could select their own pair-programming partner and they remained a pair for the whole course. All assignments were completed in pairs but solo programming was done in the practical tests and the exam.

2.2 Data Collection, Instrument and Analysis

An online questionnaire was administered to the first-year students at the end of the course, just prior to the exam. Participation was voluntary and anonymous but two extra marks for a test were used as incentive.

The number of usable responses received totalled 121, which indicates a response rate of 67%. Table 1 provides a summary of the biographic data. The gender profile is a concern but not surprising with only 31% of the respondents being female. A greater concern is the ethnic background of the students in the introductory programming class with only 8% of the respondents being black people.

Table 1. Profile of respondents (n=121)

		Number (%) of respondents
Gender	Male	83 (69%)
	Female	38 (31%)
Ethnic background	African/Black	10 (8%)
	White	103 (85%)
	Coloured	5 (4%)
	Indian/Asian	3 (3%)

The first section of the questionnaire gathered information on the biographic data of the respondents as shown in Table 1. The second section, using a Likert scale from 1 (strongly disagree) to 5 (strongly agree), asked questions on their experiences with pair programming and lastly, two open-ended questions asked: "Anything about pair programming you particularly like?" and "Any particular frustrations with pair programming?".

Through quantitative analysis the data from the Likert scale questions were summarized. 76 students (63%) provided qualitative comments. For the analysis of the qualitative data the ATLAS.ti 7.1.4 computer program was used. Content analysis was conducted on all responses from the open-ended questions and thematic analysis and frequency counts were utilised to categorise responses. Since the product of qualitative research is richly descriptive, some results are presented in the form of quotes from the participant comments.

2.3 Threats to Validity

Students could select their own pair-programming partner and were not paired according to specific criteria, such as gender or novice-expert constellations. Previous studies showed that students' skill level was the factor that affected the effectiveness of pair programming the most [22]. The results of this study might have looked different if students were paired according to skill level, but from the qualitative results it is clear that they appreciated the fact that they could work with their friends on the assignments.

3. RESULTS AND DISCUSSION

Table 2 shows that the mean values of all nine factors are relatively high. The majority of students enjoy the pair-programming experience and they are confident about their assignments and feel they complete the practical assignments faster than with solo programming. The students feel that their programs were of better quality, had less errors and they got stuck less when they were working as a pair. The item with the highest mean was the fact that students were of the opinion that pair programming will work in the IT workplace.

Table 2. Items and Descriptive Statistics (n=121)

	Mean*	Std. Deviation
I prefer pair programming over solo programming	3.492	1.494
The others in my class prefer pair programming over solo programming	3.808	1.164
I enjoy the pair-programming experience more than working alone	3.818	1.420
We completed the practical assignments faster than we would have had we worked on our own	3.850	1.333
I am more confident in my assignments because I pair programmed	3.875	1.333
We have less errors in our programs because of the pair programming	3.958	1.221
I did a better job with programming assignments because we solved them as a pair	3.959	1.339
We get stuck less when we are working as a pair	3.975	1.255
I think pair programming will work in today's IT workplace	4.033	1.128

* *Likert-style responses were ranked from 1 to 5 respectively*

The item with the lowest mean was: *I prefer pair programming over solo programming.* Further analysis revealed the following interesting facts:

- 24 students (20%) do not prefer pair programming at all.
- Of these 24 students, 22 are males, and
- 20 (17.5%) are white males.

In the qualitative data one of the 20 above-mentioned white males had the following to say about what students like about pair programming:

- *Hou minder as niks daarvan nie (I like it less than nothing at all*)

And his frustration with pair programming:

- *Ek sal dit vinniger self kan doen (I can do it faster on my own)*

On the opposite side of the spectrum the following was found:

- 43 students (36%) strongly prefer pair programming
- Of these 43 students, 8 students are black, and
- 8 out of 10 (80%) of the black students therefore strongly prefer pair programming

In the qualitative data, one of the 8 black students mentioned above had the following to say about what students like about pair programming:

- *Is good because, if you make mistakes your partner helps you to identify them and you know where you make mistakes and helps to also identify which sections you experience difficulty.*

And his frustration with pair programming:

- *No, it is vital and good for students. I would recommend it for other students*.

From the above results it is clear that students have strong opinions about pair programming and they either love or hate pair programming. Although the majority of students prefer pair programming, there is a minority group that has a strong dislike of the pair programming experience.

Table 3 shows the mean values by gender. It is not surprising that the male students are significantly less positive about pair programming than the females. The females, on the other hand, find pair programming highly enjoyable and they prefer pair programming significantly more than solo programming.

Table 3. Preferences by gender

	Mean*	
	Male	Female
I prefer pair programming over solo programming	3.265	4.000
The others in my class prefer pair programming over solo programming	3.719	4.000
I enjoy the pair-programming experience more than working alone	3.542	4.421

* *Likert-style responses were ranked from 1 to 5 respectively*

The qualitative data revealed considerably more advantages in respect of pair programming than difficulties or frustrations. Tables 4 and 5 show the qualitative results of the open-ended question "Anything about pair programming you particularly like?".

Although certain themes were covered in the questionnaire, some of the themes emerged again in the qualitative data as shown in Table 4. Students reiterated that they like the fact that pair programming results in the faster completion of their assignments. Students again stated that they enjoy pair programming, there are fewer errors in their programs and they get stuck less than when they had to do it on their own.

Table 4. Existing themes: What students like about pair programming

Theme	Frequency
Less time	12
▪ *We get an opportunity for brain- storming in a very short space of time. The problem gets solved timeously.*	
Less errors	4
▪ *It works faster and there are a lot less errors in the program*	
Enjoyment	3
▪ *Prakties is lekkerder en vinniger saam met 'n maat.*	
Get stuck less*	1
▪ *You don't get stuck as much*	

The new themes that emerged from the qualitative data are shown in Table 5. The students particularly liked the fact that they could share ideas and they believe that two minds are better than one.

Students reported how they learned from each other, helped each other and that the help was readily available. Lecturers mostly have time to teach only one way of solving a programming problem, but students learned more ways to solve a problem from their pair-programming partners.

Students reported increased comprehension and they liked that they could rely on the fact that one of them would probably know the answer. Students liked the fact that debugging of their programs is simplified when working as a pair. Students also reported that they learn soft skills, such as teamwork when working in pairs.

Students like the social aspects of pair programming and they report on a reduced workload for lecturers and assistants because they would consult their pair-programming partner. Students also reported that they could remember more of the work when they discussed it as a pair and they learn more because they are teaching their partners.

Table 5. New themes: What students like about pair programming

Theme	Frequency
Sharing ideas / 2 minds	21
▪ *Better to work together because 2 brains are better than one* ▪ *Being able to share ideas and merge them into one program*	
Learn from each other	14
▪ *Finding solutions together and being able to teach and be taught by someone who is your peer.* ▪ *I was able to learn things from my partner that I would not necessarily have learnt on my own.*	
Help each other	11
▪ *It helps to help each other with problems.* ▪ *We can share ideas about how to write programs and help each other in areas where we lack.*	
Help available	10
▪ *The fact that you have someone apart from the demi (assistant) to consult with problems.* ▪ *As jy sukkel dan is daar altyd iemand wat jou kan help.*	
More ways to solve a problem / different ideas	8
▪ *Lots of ways to solve a problem.* ▪ *Getting new ideas and problem solving abilities from your partner, making the programming easier.* ▪ *It gives me a different perspective on the work by seeing how the other person thinks or sees it.*	
Comprehension	6
▪ *In explaining certain concepts to my partner I was able to understand them better myself.* ▪ *Sometimes I understand it better when my friend explains something than when the lecturer does it on a screen.*	
One out of two knows the answer	6
▪ *When you don't know something, your partner usually does.*	
Debugging	5
▪ *It works very well for eliminating errors and solving problems are usually faster.*	
Learn teamwork	5
▪ *I feel in the work place it is essential to have social skills and I feel working in these pairs aids in that.* ▪ *You learn to work with other people and also get different ideas.*	
Reduced workload for lecturer and assistants	3
▪ *Your friend can explain to you when you don't understand, so then the assistants don't have to run around as much.*	
Sociable	3
▪ *I like the fact that you interact with people.*	
Memorisation	2
▪ *I enjoy pair programming because I remember things with greater ease when my friend explains it to me rather than when I listen in class because we are both involved in the 'conversation'*	
Learn through teaching	2
▪ *In explaining certain concepts to my partner I was able to understand them better myself.*	

The students reported very little dislikes with pair programming. The fact that pairs might have opinion and personality clashes and the fact that a partner might not contribute, are some of the

frustrations with pair programming. An absent partner is also a problem for students.

- *The only problem is the different opinions and if your partner is lazy.*
- *The human emotional factor of your partner getting irritated etc. You can't control it like a computer.*
- *Die enigste nadeel wat ek aan kan dink is dat as jou partner die dag nie op kampus is nie, dat jy of alleen sit of alleen programmeer.*

Earlier in the paper we reported on 20 white males who strongly do not prefer pair programming and one of them had the following to say about what he dislikes about pair programming:

- *Pair programming is just another loophole that allows students to copy each other's work. Legally.*

4. CONCLUSION

Pair programming is preferred by most students in the introductory programming class. There are, however, certain groups of students with a strong like or dislike for pair programming that should receive special attention. The female and black students are very positive about pair programming and this might point to a solution to the problems of few black people and few women in the computing field. The results strongly suggest that pair programming can aid in attracting and retaining black people and women.

The fact that a significant portion of the white males has such a negative perception regarding pair programming is a matter of concern. These students will probably end up as part of a software development team in their future career and the industry expects new recruits to have acquired soft skills, such as teamwork in their education. Lecturers should make an effort to inform the white male students about the use of pair programming in industry and what skills they could gain from using pair programming. Furthermore, lecturers should pay special attention to the constellation of the pairs for these white male students.

Students' experiences with pair programming were very positive: they enjoy pair programming; it is faster; they make fewer mistakes; and they get stuck less. In addition, students like that they could share ideas; learn from each other; help each other; and help is always available. Students found that with the pair-programming experience: they learn various ways to solve a problem; comprehension is improved; at least one of the pair knows the answer; and debugging is easier. More positive experiences reported include: leaning to work with other people; the educators' workload is reduced; pair programming is sociable; memorisation is simplified; and through teaching their partner, students learn a lot.

Limited resources is a reality in developing countries and pair programming can allow for educators to manage comfortably with half the number of computers required in the traditional introductory programming classes.

There were some limitations to the study. The very small sample of black students in the dataset caused that generalisations could not be made and future research should include a larger sample. Although 63% of the students provided qualitative comments, the researcher could have acquired deeper insights into students' experiences with pair programming through the use of interviews or focus groups.

Pair programming is recommended for every introductory programming class, especially in South Africa where the enrolment of women and black people in the IT field is a priority.

"*Two are better off than one, because together they can work more effectively. If one of them falls down, the other can help him up. But if someone is alone and falls, it's just too bad, because there is no one to help him (Eccl. 4:9–10)*"

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Teaching OOP Using the Qt Framework

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ABSTRACT
There are many issues to be considered when teaching object-oriented programming (OOP). These include the topics to cover, the programming language and the environment to use, and whether to use a large API or not. In this paper, we describe the topics that are taught in two modules covering OOP and design patterns, and how C++ and the Qt framework are used to do so. We also report on a quantitative and qualitative study to determine the opinions of students concerning their experience of learning OOP with this software, to compare them with the perceptions of the lecturers. By means of this comparison, we highlight issues that need to be addressed in these modules, which may be valuable to the OOP teaching community in general.

Categories and Subject Descriptors
D.1.5 [**PROGRAMMING TECHNIQUES: Object-oriented Programming**]

General Terms
Programming

Keywords
Object-oriented programming, software design patterns, teaching and learning programming, C++, Qt framework, student perceptions, lecturer perceptions

1. INTRODUCTION
It is our experience that there are a number of constraints that need to be balanced, and choices that need to be made, when teaching object-oriented programming (OOP). The constraints at our institution include the following: students struggle because the concepts of OOP are inherently difficult to grasp. Students don't always have the required background, either in problem solving, in programming, or in the programming language that is used. There is little time available for teaching these difficult concepts properly in a semester. Students, university authorities and industry require that students learn useful skills using the latest technology.

Guided by these constraints, choices were made regarding various aspects of teaching OOP such as the topics to be covered, at which levels to offer these topics, and the language and resources to be used.

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This study reflects on these choices and the consequences thereof, making use of the perceptions of lecturers and students on various aspects of teaching and learning OOP.

The motivation for such a study is twofold. To the best of our knowledge a study that uses lecturers' and students' perceptions to probe teaching and learning OOP has not yet been reported in the computing education literature. A study of this nature allows us to examine the similarities and differences in the perceptions of students and lecturers, which can be useful in improving our OOP course offerings as well as being beneficial to the OOP teaching community in general.

This paper is structured as follows: in Section 2 we give an introduction to Qt and one of its integrated development environments (IDE) as well as its usage in industry and academia. In Section 3, we give an overview of the related work involving teaching OOP, the value of frameworks in teaching OOP and how this work fits within the reported computing education research literature. In Section 4, we describe the content (and outcomes) of two modules covering OOP and the language and the framework used in them. In Section 5, we describe the lecturers' perceptions of the importance of the outcomes, and how successfully they have been achieved. In Section 6, we report on the results of a survey (comprising quantitative and qualitative data) of students' opinions on the content and objectives of these modules, and how well they are achieved. In Section 7, we compare the lecturers' perceptions with those of the students. Concluding, we suggest some plans for the future, based on this study.

2. QT AND QT CREATOR
Qt was created by Eirik Chambe-Eng and Haavard Nord in 1991, with its first commercial release in 1995. The entire framework is written in C++, and programming with it requires a solid grasp of C++. The Qt framework has features that are not supported by standard C++, such as signals and slots used for object-to-object communication and run-time introspection of objects. The Qt framework offers extensive graphical user interface (GUI) programming and mobile application development facilities.

Qt Creator is an IDE for developing Qt applications. This IDE offers comprehensive support from coding to deploying Qt applications. Among its many features are a user interface design facility called Qt Designer, a debugger, and easily accessible API documentation.

Qt is used in both commercial applications and in academia. It has been used for applications like the KDE desktop, VLC media player, Adobe Photoshop Elements, Google Earth and Skype [20]. Herala [7] notes that Qt is reportedly used in 26 countries for the teaching of programming, and that there are two basic ways in which Qt has been used:

- Teaching Qt as an end in itself.
- Teaching programming concepts where Qt is the tool used.

Where Qt has been used, it is often for teaching the principles of graphical user interfaces (GUIs), OO programming, and dealing with frameworks and class libraries [5][14], as well as computer graphics (where Qt was used as the windowing toolkit) [19], and embedded programming [18].

3. RELATED WORK

Learning to program is a non-trivial process [12][17], and has resulted in scholarly interest in understanding various aspects of learning and teaching programming. Teaching object-oriented programming (OOP) is also considered to be challenging in both introductory [9][10] and advanced programming courses [13]. There is much debate around the various aspects that contribute to the difficulty of teaching and learning OOP. These aspects include the introduction of OOP after exposing students to structural or procedural programming, the choice of programming language used [9] and the tools used such as programming environments [10] and frameworks [2].

Teaching object-oriented programming, particularly design patterns using frameworks, is recommended for various reasons. Firstly, a well-designed object-oriented framework is a working demonstration of the implementation of design patterns and its relevance in handling complexity in software systems. It also demonstrates object-oriented concepts such as class design, class hierarchies, polymorphism and delegation. Working with frameworks gets the students acquainted with the idea that software reuse is an important aspect of software development. Students hopefully gain an understanding of the advantage of using frameworks rather than doing all on their own since they can achieve much more with frameworks. On the other hand, a framework needs to be chosen carefully since it requires more effort from the student to learn it before it can be effectively used in a module [2].

There are numerous studies reported in the computing education literature that investigate experiences, attitudes, perspectives and expectations mainly of students and, sometimes, of lecturers [1][3][6][8][11][16]. Due to the prevalence of such studies, we conclude that the students' and lecturers' opinions on various aspects play an important role in understanding, and providing insights into, computing education. In this study, we have therefore attempted to explore various aspects of teaching and learning OOP using the Qt framework from lecturers' and students' points of view.

Studies that examine both lecturers' and students' expectations consider the alignment of these two sets of expectations to be ideal from an educational perspective [11]. However, misalignment of lecturers' and students' expectations is not uncommon, and such studies offer valuable insights into reducing the differences in expectations. In one study [11], the expectations of self-management, collaboration, knowledge and skills associated with specific levels of qualifications, as stated in a qualification framework, is compared to the expectations of students and lecturers in an institute that follows the qualification framework. It was found that there was a considerable difference in the expectations of the students, lecturers and the prescribed qualification framework. In another study [3], a comparison was made of the viewpoints of students, lecturers and professionals on the importance of incorporating and assessing professional values in computing curricula, revealing similarities and differences in perspectives.

Students' and lecturers' experiences, attitudes, perspectives and expectations can be broadly classified into three categories: computing in general; specific computing topics such as programming; and overarching concepts applicable in computing such as ethics and teamwork. The motivations for studies in these three categories can take two possible forms. One approach starts off with problems identified from the researcher's experience and research is conducted to explore the problems further, often including finding reasons for the problems and possible solutions to these problems. An example of such a study is to find out why the drop-out rates for computing subjects is high [16]. The second group of studies simply try to identify problems in an area. For example, a study that explores the level of alignment between lecturers' and students' perceptions and the expectations set out in a qualification framework about soft skills, such as collaborative learning, would fall into this category [11]. The study reported in this paper falls into the second category because it investigates the similarities and differences in lecturers' and students' expectations and experiences in teaching and learning OOP using the Qt framework, with the aim of improving our own course offerings as well as sharing our insights with the teaching community in general.

One review [15] classifies the literature on the teaching of introductory programming into four categories: curricula (what is being taught); teaching pedagogy (how it is being taught); the programming language; and the tools used in the course. Although [15] focuses on introductory programming, these four categories can be applied to any programming course. The present paper considers lecturers' and students' experiences in similar categories, extending the notion of tools from merely software tools to all resources used to support learning and teaching in two programming modules.

To the best of our knowledge, there has not yet been a study reported on the teaching and learning perspectives of lecturers and students of OOP focused around a framework, especially the Qt framework. The lack of such studies is a sufficient motivation for this study.

4. CONTEXT

At our institution, OOP is taught on all three levels of our undergraduate Computer Science major. On first-year level, there is a module providing an introduction to OOP, on the second level there is a module with a more comprehensive focus on OOP, and on the third level an advanced module.

Object-orientation is also used in another second level module on data structures and algorithms. The first year introduction to OOP is a prerequisite for both second-year modules.

In the first level module, only rudimentary OO concepts like the difference between classes and objects, the definition of a class, and the notation for accessing members of an object, are covered. Students are made aware of inheritance, but are not required to implement inheritance hierarchies.

In the second level (more comprehensive) module, encapsulation, inheritance and polymorphism are covered extensively. Basic GUI programming is also covered in this module. The module also contains an introduction to software design patterns (SDPs), where a few patterns are discussed in terms of their application in a software framework.

In the third level (advanced) module, SDPs are covered in more depth and students are expected to apply them in problems of limited scope. This module also touches on reflective

programming, concurrency, parsing XML, some network and web programming, and regular expressions.

For all programming modules, students are required to demonstrate their understanding of the relevant concepts by applying them correctly in programs of low to medium complexity.

For all modules involving OOP, C++ is used as the programming language. The Qt framework is only used in two modules – the more comprehensive module on the second level and the advanced module on the third level. For these two modules, students are required to use the Qt Creator IDE to develop their programs. The same textbook is prescribed for both these modules.

4.1 Using Qt for teaching OOP

Encapsulation can be taught quite easily without a framework. In particular, a language like C++, with its standard libraries for strings and containers, is quite sufficient to teach students correct class structure and the use of access restrictions to ensure proper encapsulation of data members with member functions. However, it is possible to exclusively use the string and container classes provided by the Qt framework, e.g. `QString` and `QList`, to teach the principles of encapsulation.

For inheritance, the Qt framework has an advantage over the standard libraries, since it provides powerful GUI classes like `QDialog` and `QMainWindow` from which one can inherit to define one's own dialog and window classes. In this way, students can see the real advantage and power of inheritance.

For polymorphism, there isn't a particular advantage in using a framework. Nevertheless, the Qt framework is quite conducive for explaining and illustrating the important concepts of polymorphic assignment and dynamic binding since it provides a complex inheritance hierarchy of classes where polymorphism is essential.

Design patterns can be taught easily using the Qt framework since many of these patterns and principles are already applied in the framework. For example, the Composite pattern is applied in the child management facility of widgets, the Observer pattern is applied in the signals and slots mechanism for event handling, and the Command pattern is applied in the design of the `QAction` class. These applications can be discussed and contrasted with the classic design patterns of GoF [4] to give students a good idea of what design patterns are and how they work. The framework is also conducive for teaching the application of other design patterns like Abstract Factory, Singleton and Façade. These can be used to develop programs of high complexity, showing the real power and usefulness of design patterns.

The Qt framework can be used to teach other OO concepts, principles and architectures. These include the concepts of reuse, cohesion and coupling and principles like single responsibility and separation of concerns. The framework also contains classes that allow a model-view-controller (MVC) architecture to be easily implemented.

5. LECTURER PERCEPTIONS

To try to establish a contrasting view to that of the students, the three lecturers who teach the two modules involving OOP and the Qt framework specified in Section 4 were asked to share their perceptions of what they considered the important outcomes of the modules to be, as well as how effectively they thought these outcomes were achieved. They also gave their opinions on the resources used (and available) for teaching these modules.

5.1 Perceived Important Outcomes

To elicit opinions on the outcomes, consensus was firstly reached on a list of outcomes, and then each lecturer independently wrote how important he/she considered them to be, and to what extent students managed to attain them. Their opinions can be summarised as follows:

(1) Understanding object-oriented programming concepts

All three lecturers considered this outcome as important. OOP is an internationally accepted part of the Computer Science curriculum and OOP languages like C++, C# and Java are used extensively in industry. Students should not only have a theoretical understanding of these OOP concepts, but should be able to demonstrate this understanding by applying it to programming problems.

There was some difference of opinion as to how well this outcome is achieved. Since the pass rate for the second level module is low, it is true that few students manage to master OOP concepts. One lecturer thought that students who did manage to pass both modules do gain an understanding of these concepts. However, a lack of ability to apply these concepts habitually or correctly in assignments on the third level seems to indicate that students have not grasped them sufficiently. This may be because there are students who manage to pass the second level exam on book learning alone.

(2) Mastery of C++ object-oriented constructs

This outcome is necessary to fulfil outcome (1). However, C++ could easily be replaced by another OO language.

Students who attain outcome (1) should attain outcome (2) as well since one can argue that it is virtually impossible to understand OOP concepts properly without learning an OO programming language and mastering its OO constructs.

(3) Effective use of a large software framework like Qt

There was agreement that this is an important outcome, as it can be used to teach OOP concepts, including reuse. Students can see the OOP concepts and principles applied in the framework, and are required to design their code correctly to use the framework properly. Students need not learn to use the entire Qt framework. Furthermore, other large software frameworks like C# or Java could serve the purpose. Learning to use the Qt framework effectively ought to help students learn to use other frameworks more easily.

One lecturer doubted whether students manage to learn to use the Qt framework effectively. The hope was expressed that they learn enough to be able to teach themselves more of the framework.

(4) Ability to create simple, quality GUI applications

It was agreed that students should be exposed to GUI programming somewhere in the curriculum. However, one lecturer felt that it isn't essential for learning OOP concepts, although it helps to make the qualification more marketable. Other types of programs (e.g. console apps) can also serve the purpose of meeting outcome (1), but are perhaps more boring and less marketable.

The lecturers agreed that students who pass the two modules do attain this outcome.

(5) Familiarity with the Qt framework

There was agreement that it is less important that students have a mastery of the entire Qt framework. One lecturer felt that students should not be required to know and remember the intricacies of various classes, but that they should understand the structure of Qt and how to use a selection of its structures to achieve certain aims (or solve certain types of problems or create certain types of apps). However, these should serve the purposes of outcome (1). Students are not required to learn the whole Qt framework, but this isn't a problem since this isn't the purpose of the modules.

(6) Ability to apply Qt specific techniques/facilities like signals and slots, concurrency, etc.

There was agreement that it is necessary for students to be able to apply such techniques effectively. However, they are not ends in themselves. They should serve the purposes of outcomes (1), (3) and (4). For example, concurrency is an important outcome, and to show that they understand it properly, students have to be able to write programs using particular facilities of the Qt framework. Students would probably prefer to use the Designer to deal with the technicalities of signals and slots, but there is value in getting them to code this themselves to get a proper understanding of the techniques, and of the issues of event handling and the Observer pattern.

The opinions were mixed as to whether students manage to apply these more technical aspects of the Qt framework properly. But this is perhaps not critical.

(7) Ability to apply SDPs like Abstract Factory, Singleton and Façade

SDPs are an important aspect of higher-level OOP, and so to cover outcome (1) to an appropriate depth, students should understand and be able to apply SDPs. If students want to be able to solve complex software problems (no matter what language or technology) they need to understand and be able to apply SDPs. There is a related outcome of knowing (or being able to determine) when it is appropriate to apply a particular SDP.

Students struggle to attain this outcome (both the when and the how), for the following reasons: SDPs are complex, the prescribed book explains them poorly, and students don't understand the foundational concepts on which they are based well enough. Also students don't get the opportunity to apply SDPs in complex problems where their application makes more sense.

(8) Sufficient understanding to teach themselves to use other technologies, languages and frameworks

There was mixed opinion on the importance of this outcome. On the one hand, if students only learn to program in C++ and use the Qt framework without being able to transfer this knowledge to other languages and technologies, not much has been achieved. On the other hand, the lecturers hope that students will achieve this outcome to some extent without it being made explicit.

The lecturers found it difficult to determine to what extent students manage to attain this outcome. Perhaps the fact that only one language and one framework is used in the Computer Science curriculum means that students don't manage to abstract/induce the principles from the specific technologies.

5.2 Resources

Lecturers identified the resources that they use in teaching the appropriate modules, and evaluated them in terms of achieving the above outcomes:

(1) Prescribed book

There was general agreement that there were problems with the textbook that is currently prescribed for the two modules, but there was some difference of opinion on how bad it is. The following problems were identified:

- Examples are overcomplicated and unclear
- Examples are incorrect (and some do not compile)
- Examples don't always follow good design/programming principles
- The ordering of topics isn't good; they are often handled in an ad hoc (rather than a systematic) fashion
- There is repetition and omission of certain material
- Too much emphasis is placed on Qt features and too little on OOP concepts and principles, and SDPs
- Some explanations, particularly of SDPs, are simply incorrect or misleading

There was agreement that there isn't another textbook available that covers OOP and SDPs using the Qt framework. The only alternative would be to write material ourselves, since choosing another book would require switching to another programming language and/or framework.

(2) Qt framework

Only one lecturer commented on the Qt framework itself as a resource. The opinion expressed was that the Qt framework serves the purposes satisfactorily (i.e. it can be used meaningfully to achieve the stated outcomes of the modules). The non-C++ syntax used for the meta-object compiler (MOC), in particular, signals and slots and the MOC macros, is not entirely satisfactory. It is a perception that students might be more employable if they could state that they were proficient in some other more popular framework, but if they manage to learn the principles of OOP, how frameworks work and SDPs using the Qt framework, then they should be able to transfer their knowledge, i.e. teach themselves other technologies and apply the same principles.

(3) Qt Creator

There was agreement that this programming environment is usable and includes good API documentation and useful examples. There are some technical issues like the adjustments one has to make to the project file which are irritating, but otherwise it is easy to use. One lecturer wondered whether the use of an IDE doesn't sometimes make things too easy for students. In particular, they never need to compile and link projects at the command prompt, and don't need to compile separate libraries and link against them.

(4) Qt Designer

Only one lecturer commented on the Designer and was not in favour of students using it for the development of all their GUI apps. There is merit in getting students to define their own classes that inherit from dialog classes, define their own signals and slots and connect them appropriately to implement event-handling. The Qt Designer does this all for you and so short-circuits this learning process. Once students can implement a dialog class manually and have mastered the use of signals and slots, there should be no harm in allowing them to use the Designer.

(5) Other resources

One lecturer commented briefly on the following four additional resources:

- Qt Assistant: Contains valuable material with clear explanations and useful example code.

- Other textbooks: There are other books that focus on the Qt framework, but not the OOP concepts and SDPs that we want. One possibility would be to use such a book to teach the technicalities of the Qt framework, and cover the other outcomes with our own material.
- Internet: There are some good websites with videos on applying Qt techniques. There is also a limited amount of code examples and explanations available.

6. STUDENT PERCEPTIONS

In order to gauge students' views on the use of Qt, programming students from the two relevant modules were surveyed, and the responses analysed.

The questions in the survey were designed to elicit students' views on the usefulness of Qt in learning OOP and SDPs, the value of frameworks like Qt, comparative relevance of learning Qt to learning OOP and SDPs, whether they would continue using Qt after completing their courses and the usefulness of the various resources used in these two modules, which includes Qt itself, Qt Creator, the debugger, the Qt documentation and the prescribed book. A few questions were also included to obtain students basic demographic details and programming background. Additionally students were given the option to comment on any other aspect of these two courses that was relevant to them.

The topics that were included for obtaining lecturer perceptions is not entirely aligned with the questions included in the survey for the students. While the topics for lecturers centred on the outcomes, the questions in the survey were centred on how Qt helped in learning these outcomes. For example, lecturers could comment on the importance of applying SDPs but students were not asked to comment on this outcome, but rather on how Qt helped to understand and apply SDPs. Students also did not get explicit questions about other resources that can be used in these courses although they were allowed to indicate such resources.

6.1 The Survey

Students from the two programming modules where Qt is used were invited to take part in an online survey via an announcement sent out on the university's learning management system. Both current and supplementary students that wrote the semester exams at the end of the second semester in 2014 were invited to complete the survey. This invitation was made once the teaching in the semester was complete, and just before the exams were to be written. The survey remained open for submissions for a period of four weeks. In this time, of the students who were sent the invitation-to-participate announcement, there was a 16% response rate (although the response rate was much higher in the third-year module (22%) as compared to the second-year module (12%)). The survey contained both Likert-style and open-ended style questions.

The majority of the respondents were male (76%). Furthermore, Qt was being used in a mainly Microsoft Windows environment (90%) with some usage in Linux (13 respondents) and, to a lesser extent, Mac (6 respondents), with some students working in more than one operating system environment.

6.2 Survey response discussion

In this discussion of the results, response identification numbers (indicated by #) will be used where direct reference is made to comments made by respondents.

(1) Learning in the context of the Qt framework

There was a mixed response to the idea of learning to program using the Qt framework, although there were substantially more negative comments made about Qt than positive ones. There were students who "loved" (#16) the framework, found it a "gem" (#73), and were "impressed" (#27, #46, #81) by it, partly because it "adds features that makes c++ easier to use" (#103), "encourages [the] student to experiment" (#103), and "makes life more easier (sic) to write complex applications" (#92). However, there were also those who "[d]isliked the entire framework" (#8), believing that it should not be taught at all (#15), and that is it is "tedious" (#56) and "way too complicated for me to understand" (#45). There is an opinion that it is "BAD" and that there "are better frameworks" available (#91). Some students found Qt difficult to grasp (#94) and believed that it "added overhead to programming" (#99). Additionally, one student noted that it was "considerably easier to use than other C/C++ IDEs I have used before" (#32).

Questions were raised about the use of Qt as it is not a "major player" (#12), "representing [a] niche other than the norm in software development" (#12), with "easier cross platform languages such as python" (#22) being available. The changing ownership of the Qt framework also led to "uncertainty to its stability" (#15). A student further claimed that "it is less motivating" where the framework is not "directly related to the current and future job demands" (#41), resulting in it being of "no use for me" (#79). This negative view was not without challenge, and one student believed the Qt framework to be "a rich and solid C++ framework and … widely adopted" (#46). The features of the framework that did work in its favour, however, was that it was useful for "developing cross platform applications" (#37) and had a focus on mobile apps (#14, #68). That it is an "open source tool accessible to all" (#35) was also seen as an advantage.

Some students did not see the point of learning in the context of a framework in the first place, commenting that there "is no reason Qt should be used above plain C++" (#43) and that "[p]lain C++ can explain these core concepts quite sufficiently" (#43). Additionally, there was the feeling that "I was no longer learning about programming but how to use Qt" (#48). Moreover, it was noted that learning Qt-specific concepts was problematic as "you won't be able to use it outside the Qt framework" (#13). However, one student argued that it is not a matter of whether to learn pure C++ or Qt, but that the "two ought to be complimentary, not substitutes" (#107).

Considering that it was noted that learning Qt did "make me aware of alternatives to frameworks such as .NET and Java" (#72), it does appear as though there is not a general dislike of frameworks as such, but just of the Qt framework, as some students noted that they "wouldn't object to trying any other framework, like Microsoft Visual studio" (#45) or "it would have been better to just learn standard Java" (#13), and that "instead of Qt I would recommend c#" (#68). Added to this is the "whole idea of forcing one frame work to 3rd year students" (#41). Other students found learning via the Qt framework to be a "great learning experience" (#78), and that its similarity to the ".NET Framework allowed me to pick it up easily" (#46).

(2) When to start using frameworks in the learning process

As was seen in other responses to the use of the Qt framework in learning programming, there was also a mixed response to the idea of introducing this framework at first-year level. Mostly, though, the argument was that, as "Qt is an expansion of C++" (#49), beginner programmers should be "taught the fundamentals

of C++ before being taught the Qt framework" (#36), and that programming concepts "may be best taught independently of a framework so that learners are aware that they are applicable in any language or framework … Framework independent concepts are more useful" (#37). There was also the fear that introducing Qt could "lose the fundamentals of programming" (#48), leave a first year student "lost" (#73) and "confused" (#56), and lead to "failure of 1st years as Qt is not easy to understand" (#71). This is not a universal feeling, and one student argued that it would "have been better if we got introduced to Qt from [the] beginning" (#79) as first year only taught basic programming that did not provide much of a challenge.

(3) The importance of using a framework

When asked to compare the relative importance of learning a technology like Qt to learning programming concepts and principles, 75% of the respondents who answered this question felt that it is either less important (49%), or not at all important (19%), to learn such frameworks. It does need to be noted that there was no option to say that they are of equal importance, forcing respondents to fall to either one or the other side of this statement.

(4) The value of the prescribed book used

In general, the prescribed book for the module was felt to be a valuable resource by only 36% of the students, and comments about it include that it is "hardly useful" (#18), even "useless" (#45, #69, #71). Students found it "really difficult to follow" (#83), not "comprehensive enough to teach certain concepts" (#35), and "confusing" (#45), arguing that is one of the "worst" (#28, #53) textbooks they have ever had to use.

It is possible that the poor quality of the prescribed book has led to some of the negative feelings about using the Qt framework. This theme is picked up in comments that note that the prescribed book "let the learning framework down a bit for me" (#25), and that expectations for the module "cannot be accomplished with the current prescribed book" (#40); thus a student wondered if "just a better text book would make the difference" (#48). Along these lines, one student noted that "Qt becomes much easier once one is familiar with it" (#35), recognising that there was a steep learning curve. Furthermore, one student noted that there isn't "time for another technology … that is not being used in the work place" (#79).

7. COMPARISON AND DISCUSSION

Although it may not be universally clear that there is value in using frameworks in the process of learning to program effectively, there is no doubt that both students and lecturers see the value of learning OOP. The fact that the Qt framework is only introduced in the second year backs up the students' perception that such frameworks may only serve to confuse the beginner programmer, and that the fundamental programming concepts need to be mastered before the use of frameworks is initiated. But it is a concern that only a small percentage of students found value in learning in the context of a framework, believing that simple programming constructs would be enough. This may point to the need to clearly point out the value of such frameworks in these modules.

One can speculate about the various reasons for the majority of the students disliking Qt. One reason could be the steep learning curve associated with learning a framework [2], which is obvious from some students' comments. Perhaps the time-constrained semester system, where students have to learn Qt on top of the OOP concepts covered in these modules, could contribute to their attitudes. Negative perceptions of its usefulness could be another reason for students' dislike of learning Qt. If proficiency in Qt is not a marketable skill, then it is understandable that students are not keen to learn it. It is noteworthy that there have been cases where Qt was used initially in an academic institution, and then replaced with VBA as this was more in demand by employers [14]. General dislike of the prescribed book could also be another reason why students dislike Qt.

While the lecturers agree on the importance of frameworks, students not finding value in using frameworks could point to some problems with these courses. The value of frameworks in software development is not emphasised, and examples from Qt are not always used to explain OOP concepts, principles and SDPs. Including examples of limited scope in these courses may also undermine the perceived value of software reuse that frameworks offer.

There are also some differences in perception as to the ability to learn other frameworks, having learnt one. While the lecturers were quite comfortable with the idea that Qt is merely a tool with which to implement OOP design, and one that displays OOP principles, students are obviously more oriented towards the future employment market because they do not yet know the transferable skills they have learned from Qt. For such students, there is little point in using valuable time and cognitive resources on something that is not going to be immediately useful on graduation. This could be seen as short-sightedness on the part of students as a career in programming is sure to involve life-long learning, and taking concepts from one programming environment to another is probably going to be a reality in any programmer's life. On the other hand, there seems to be little value in lecturers clinging to a particular framework if it could be replaced with one that is more useful to students without losing any learning objectives in the process.

Pragmatically, the decision of which framework to use was based on neither the particular value offered by the Qt framework nor on what would benefit the students most. Ultimately, it was factors anchored in the larger curriculum that forced such decisions – C++ is the language that is used in the first year, and to attempt a shift to an alternative language (no matter how close to C++ it might be) within a semester-based system is unlikely to lead to success in modules that attempt to cover the required outcomes while at the same time teaching a new programming language.

It is likely that the use of frameworks will remain a focus of some of the programming modules, recognising their value, but that a move to an alternative one may have to wait for a complete redesign of the programming stream.

8. CONCLUSION

We believe that it is possible to teach OOP concepts and design patterns successfully using the Qt framework, as outlined in Section 4.

However, based on the comparison and discussion in Section 7, which summarises the misalignment of lecturers' and students' perceptions, we suggest the review of certain aspects of the OOP courses.

Employability is a driving factor for students and when choosing a framework, it is ideal to choose a popular framework or library used in the industry. If such a choice is not possible, due to curriculum and time restrictions as in the current case, students

need to be made aware that they are still learning transferable skills that they can use with other frameworks as well.

To make sure that students understand the value of frameworks, their value needs to be emphasised. This could be done by making the benefits of a framework more explicit, and by showing where the principles of OOP have been implemented in the framework itself, and how they are in fact being used in student assignments. Students could also be exposed to complex applications where the value of frameworks is obvious.

There was a large degree of agreement between lecturers and students that there are serious problems with the prescribed book. This is clearly an area of concern, and one of the questions that needs to be explored further is whether a different book could change attitudes towards Qt specifically, and the use of frameworks in general.

To conclude, academic institutions cannot always follow the trends in the industry. Although the intention may be to teach generic and transferable skills, students need to be made aware of the value of these transferable skills. It is likely that the course material, including the prescribed book, is probably the students' first experience with a framework. Such material should therefore be chosen carefully and prepared in such a way that it contributes to a positive learning experience.

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Automated Language Processing and Semantic Classification Software: A First Effort to Examine the Relationship between Distance Student Online Discussion Forum Discourse and Learning Performance Outcome

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ABSTRACT

The online discussion forum (ODF) is one of the most widely used e-learning tools available in Open Distance Learning (ODL) environments. For this reason, a popular line of research focuses on producing instruments that can be used to assess the level and amount of learning that take place via transcript analysis of ODF discourse.

This paper documents a first effort by the current author to use automated Language Processing and Semantic Classification software to examine the relationship between student ODF discourse in a web-based course where the ODF was central to the teaching and learning strategy and instructor-assessed student learning performance outcome. As input to the software is the individual student ODF discourse as extracted from the forum software database. As output is the key central semantic cores (word categories and subcategories) of the text purported to hold the essentials of the meaning of the full text. In searching for a relationship, student learning performance outcome is employed as the dependent measure, with the identified cores acting as the independent variables. Despite a small sample, and in reporting significant correlations for 42% of the word subcategories, 50% of the word category totals and for the grand total of all word categories, ample scope for further investigation is created.

Categories and Subject Descriptors

D.3.3 **[Information Interfaces and Presentation]**: Group and Organization Interfaces – Web-based interaction.

General Terms

Human Factors

SACLA 2015, 02-03 July, Johannesburg, South Africa

Keywords

Online discussion forum discourse, automated content analysis software, open distance learning, semantic analysis, student learning performance outcomes.

1. INTRODUCTION

The online discussion forum (ODF) is a popular tool used in open and online distance learning (ODL) environments. ODFs are not only used to a varying degree in different online academic programs, but also in widely different ways. For example, they can be used for social interaction only, for discussion of assignments and other assessable work, as a collaborative tool for individual project groups, for tutorial purposes, or as a central part of the teaching strategy [24].

Academics and researchers have taken an active interest in what students are saying and writing in ODFs for various reasons, e.g. to understand the processes when students engage in an ODF, the practices they adopt, how they interact with the content available, how these interactions change over time, how to measure if learning has taken place, and how to evaluate the effectiveness, or the specific dynamics of collaboration [4]. Such information helps teachers to improve e-learning systems [27].

To provide the necessary insight into the actual collaborative processes and contextual factors that affect collaboration [30], and to discover and describe the focus of individual, group, institutional, or social attention [33], ODF discourse needs to be subjected to content analysis. A broad definition of content analysis is "any technique for making inferences by objectively and systematically identifying specified characteristics of messages" [15] (p. 14).

Content analysis has been used "since the dawn of time" to interpret sacred and profane texts and, in not a few cases, to attribute texts' authorship and authenticity [19]. The process of content analysis, however, is not necessarily straight forward. A fictional, but largely autobiographic scenario [28], highlights some of the challenges of content analysis in an educational environment:

"A mildly exhausted Professor Jones, who has just completed an online course, attempts to reflect on the success of her course by analyzing readily-available transcripts of student messages generated over 13 weeks on a forum for evidence of higher-order thinking. She is quickly disappointed when the 950 messages take her 4 days to analyse. Attempts at cutting and pasting illustrations of higher-order thinking into a word-processor… result in a hodge-podge of de-contextualized quotations. Running out of time, she finds a set of criteria in the literature and hires two students to review the messages and identify certain constructs - only for them to disagree on 70% of the categorizations, while one has identified 2032 incidents and the other only 635. Feeling overwhelmed and depressed, Professor Jones returns to the literature only to find that most of the methodological issues she has been dealing with have not been addressed by major researchers in the field. She also finds that there is no coherent, long-term tradition of researchers who have resolved the methodological problems".

Whereas the above was presented as the motivation for a new framework to support content analysis of ODF discourse, the authors noted nearly a decade later [8] that the challenges as illustrated in this scenario not only remain in existence today, but were extended to include epistemological issues related to the forms of learning that are exposed in transcripts, the choice of best unit of analysis, and an inherent challenge of identifying and counting many more interesting variables.

The act of content analysis (covering both the coding and analysis processes) has also been described as tedious, laborious, challenging and time-consuming [8] [9] [28]. To solve this problem, there is a move (back) towards quantitatively- and student-driven questionnaires (e.g. see [8] for an example within the influential Community of Inquiry (CoI) framework). The appeal of a questionnaire is that it can be employed in-course at any-time, allowing the instructor quick access to information. However, the repeated use of the same survey questionnaire within the same subject pool can easily lead to deception as respondents become more sophisticated [26]. The net result is that educators are unable to make informed decisions on the extent to which they can apply a particular framework in their own settings [31].

For such reasons, the use of an automated content analysis instrument appears a viable alternative. Long recognized by scholars, automated content analysis seeks to unite two bodies of work – the literature on classical human hand coding and computer science and computational linguistics on natural language processing [25].

A search of the literature, however, has revealed a dearth of research on automated content analysis of ODF discourse, and subsequently, a resultant lack of theoretical models or concepts to drive such analysis. For the reason that ODF discourse is text representing language that emerges within a specific educational setting based on certain subject matter that exists within a certain domain of specialisation, it implies that such analysis must be able to identify the essential meaning of the text. Semantics is a sub-discipline of linguistics that focuses on the meaning of text, and as such may well offer the required theoretical grounding for automated content analysis of ODF discourse.

This main purpose of this paper is to document a first effort of the current author to use automated Language Processing and Semantic Classification software to investigate the relationship between student ODF discourse in a web-based course where the ODF was central to the teaching and learning strategy, and instructor-assessed student learning performance outcome. As input to the software is the individual student discourse as extracted from the ODF database. As output is the key central sematic cores (word categories and subcategories) of the text purported to hold the essentials of the meaning of the full text. In searching for a relationship, instructor-assessed student learning performance outcome is employed as the dependent measure, with the identified cores acting as the independent variables.

The paper is structured as follows. Firstly, a concise background to the study and related literature is presented. Thereafter, the progression that led to the choice of the automated semantic content analysis software is motivated. This is followed by an explanation of the method and research approach employed, inclusive of the research setting, data sources and design. After a presentation of the raw data collected, the results of various statistical procedures employed are relayed. Given the preliminary nature of the current research and the acknowledgement that the current author does not consider himself to be a linguistic expert, the discussion that concludes this paper focuses on further research opportunities.

2. BACKGROUND TO THE STUDY AND RELATED LITERATURE

Earlier evaluation methodologies employed to determine user satisfaction of computer conferencing used either standard evaluation methods (e.g. surveys/questionnaires), or surface level characteristics [23]. Examples of the latter are participation degree as determined by the number of messages sent; mean number of words that was assumed to positively relate to the quality of the message's content; thread-length; and social network analysis [30]. A further general method that is increasingly attracting research interest is educational data mining [4] which allows for the discovery of more complex user behaviour patterns. Conventional data sources range from data extracted from learning management systems to student transcripts (e.g. when a particular learning object was accessed and the final grade earned).

What was (and is) missing and paradoxically least used in the above methods, is the most obvious data – transcripts of the conference interactions [23]. Content analysis, first used in the 19th century [13], has been defined as a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding [19]. Since 1992, at least 15 content analysis instruments have been suggested by various authors, with the earliest the model of Henri [14] and the most resent a framework suggested by Weinberger and Fischer [34].

Content analysis is a method that may be used with either qualitative or quantitative data, and in an inductive or deductive way. Which of these methods is used is determined by the purpose of the study [30]. Specifically, and in the quantitative approach, ODF discourse is coded and summarised with frequencies/percentages used for comparisons and/or statistical testing. There against, the qualitative view uses a variety of methods such as participant observation, case summaries, and ethnomethodology to infer trends or a specific phenomenon in transcripts without computing frequencies for statistical testing. Also, if there is not enough former knowledge about the phenomenon or when this knowledge is fragmented, the inductive approach, where categories are derived from the data itself, is used [21]. Such an approach is useful when the structure of analysis is operationalized on the basis of previous knowledge [20], or where the researcher wishes to retest existing data in a new context [2].

One classification [18] categorizes applications of content analysis into three distinct approaches: a conventional content analysis approach is where the coding categories are derived directly from the text data; a directed approach where analysis starts with a theory or relevant research findings as guidance for initial codes; and a summative content analysis approach that involves counting and comparisons, usually of keywords or content, to be followed by the interpretation of the underlying context. The authors further note that whereas these approaches are used to interpret meaning from the content of text data, major differences are evident in the coding schemes, origins of codes, and threats to trustworthiness.

In addition, content analysis remains a flexible method with no simple guidelines for data analysis - thereby making its use challenging for the researcher [6]. Exacerbating the problem is that each inquiry is distinctive, with the results dependent on the skills, insights, analytic abilities and style of the investigator [17]. Several disadvantages have been suggested - both theoretical and procedural [1]:

- it can be extremely time consuming
- it is subject to increased error, particularly when relational analysis is used to attain a higher level of interpretation
- it is often devoid of theoretical base, or attempts too liberally to draw meaningful inferences about the relationships and impacts implied in a study
- it is inherently reductive, particularly when dealing with complex texts
- it tends too often to simply consist of word counts
- it often disregards the context that produced the text, as well as the state of things after the text is produced
- it can be difficult to automate or computerize

Of particular interest to the purpose of the current study are the following disadvantages: it is often devoid of theoretical base; it tends too often to simply consist of word counts; and it can be difficult to automate or computerize.

On face value, the field of linguistic semantics, with its relatively solid theoretical base, makes use of units of analysis that surpasses simple word counts by means of sub-words or sub-units (such as affixes and even compound words and phrases) in an attempt to understand the meaning and relations of words. The use of semantic units of analysis would therefore negate the first two disadvantages. As for the 3rd disadvantage, the field of semantics has several branches, and while not precise, automated software products for some branches are available.

3. AUTOMATED SEMANTIC CONTENT ANALYSIS

A recent burst of interest in automated content analysis methods is partly due to the proliferation of easy-to-obtain electronic texts [11] generated through increased connectedness and resultant mass communication. For example, it has been largely used to deeply analyse and understand political speeches [11], Twitter comments [3], Facebook posts [12] and legal text [7]. Further uses include event image assessment [29] and audio/video content consumption [22].

It is not the purpose of this paper to provide an in-depth review of the field and/or methods available in automated content analysis. For this reason, Figure 1 provides a high-level visual overview of the methods available by outlining the process of moving from collecting texts to applying the correct method.

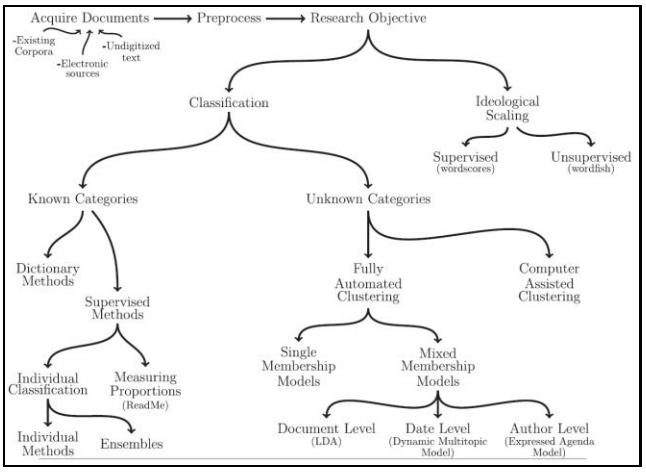

Figure 1. An overview of text as data methods [11]

Suffice to state that a large body of knowledge has been generated, with current research largely focused on validating methods as it relates to the analysis of a variety of mass communication texts. Once again, the methods proposed vary depending on the research objective.

A relevant purpose of semantic interpretation of discourse is the assignment of meaning(s), where the latter consists of conceptual objects of various degrees of complexity, depending on the complexity of the corresponding expressions [32]. The current author thus embarked on an online search for available automated content analysis software that fits this purpose.

A logical and first requirement was that it had to be free software. A second requirement was that it should be easy to use. Cognizance was also taken of a warning that discourages the use of commercial-type tools for quantitative text analysis - the reason that a broader set of tools allow the user to determine if the methods included in the software are optimal for the particular problem at hand [11].

A first and promising automated software tool found and tested was the "ReadMe software package for R" (http://gking.harvard.edu /readme). Using prescribed methods [16], the software requires as input a set of text documents (such as speeches, blog posts, newspaper articles, judicial opinions, movie reviews, etc.), a categorization scheme chosen by the user (e.g., ordered positive to negative sentiment ratings, unordered policy topics, or any other mutually exclusive and exhaustive set of categories), and a small subset of text documents hand classified into the given categories. The majority of the parameters, however, must be manually configured and entered, thereby making it inaccessible to non-technical user.

Further searches uncovered numerous other software packages. All of these, however, were either discontinued, required input above the skills of the non-technical end-user, or were commercial products.

A software package known as Tropes (http://www.semantic-knowledge.com) appeared to tick all the boxes. Formerly commercial but now free, Tropes reduces text to its essentials by making use of natural language processing and a semantic engine that contains hundreds of thousands of preset semantic classifications and reliable analysis techniques resulting from years of scientific research. With reference to the meaning of words, the software includes following features:

- automatic generation of hierarchical concepts (ontology or thesaurus generation)
- automatic semantic and syntactic ambiguity solving
- automatic semantic analysis and categorization
- text summarization
- chronological discourse analysis
- three-layer automatic concept classification
- natural language ontology manager with ready-to-use classifications

In summary, Tropes promises to provide answers to questions such as "What is the content of a text/What is a text about?" and "What are the core elements which must be identified in order to grasp the essential meaning of a text?" The tool is derived from a theoretical conception of the text which describes both the textual organization of the things that are said and the structural organization of the thought-processes of the people who say them. For this reason, subjectivity of the investigator is excluded – at least until the analysis is finished.

The advantages of Tropes, according to its web site, include its ability to carry out stylistic, syntactic and semantic analyses and to present the results in graph and table form; stylistic/rhetorical analyses (argumentative, enunciative, descriptive or narrative style; identify different word categories (verbs, connectors, personal pronouns, modalities, and qualifying adjectives); conduct thematic analyses (reference fields); and detect discursive/chronological structures. Tropes also allows the user to create personalized "scenarios" to meet own specifications. It thus fits the requirement of a broad base (and scope) of tools with which to pursue discourse analysis [11].

Figure 2 provides a screenshot of the tool interface, with the main analysis results displayed on the left of the screen, and the text extracts (and in this view, graphs) shown on the right.

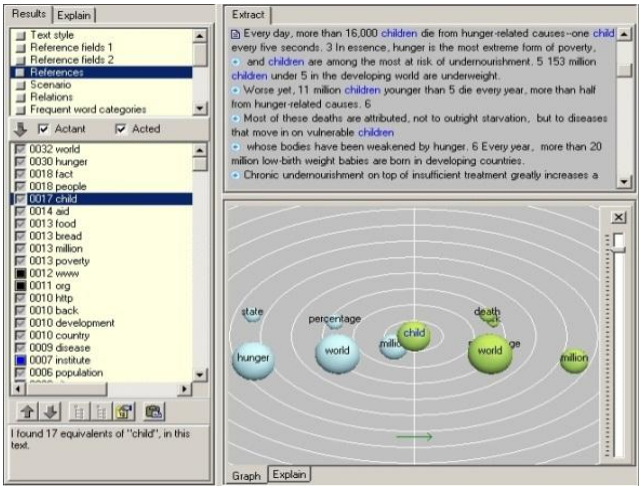

Figure 2. The Tropes interface

After a period of familiarisation the author decided to limit his first effort to generate statistics on the total occurrence frequency of main word categories and subcategories. The analysis performed is highly complex, and for purposes of this paper, only the most relevant descriptions of the analysis engine are provided. For a more in-depth description, the reader is directed to https://cyberlexport.wordpress.com/ produse/tropes-2/bibliografie.

To process text, the semantic engine operates in 6 stages:

1. sentence and proposition hashing
2. ambiguity solving (with respect to the words of the text)
3. identification of equivalent classes (senses)
4. statistics, detection of bundles and episodes
5. detection of the most characteristic parts of text
6. layout and display of the result

During this process, the software will:

1. assign all the significant words to the several main categories
2. analyze their distribution into subcategories
3. examine their occurrence order, both within the propositions and throughout the text

These word categories and subcategory scales are presented in Table 1. In listing the subcategories, a brief explanation is provided

which appears to capture some of the essences of discourse that one would expect in an academically-oriented ODF.

Table 1. Word categories and subcategories (semantic analysis).

Word Category	Word subcategories scales
Verbs	• factive, i.e. expressing actions ("to do", "to work", "to walk", etc.) • stative, i.e. expressing states or concepts of possession ("to be", "to stay", etc.) • declarative, i.e. expressing a statement about circumstances, beings, objects, etc. ("to think", "to believe", etc.) • performative, i.e. expressing an act through the language and contained within the language ("i promise", "i demand", etc.)
Connectors (conjunctions, conjunctive phrases)	Link together various parts of the discourse through concepts of: • condition ("if", "in as much as", "in case", etc.) • cause ("because", "in consequence of", "therefore", etc.) • goal ("so that", "in order that", etc.) • addition ("and", "moreover", "along with", etc.) • disjunction ("or", "either… or", "whether… or", etc.) • opposition ("but", "nevertheless", "however", etc.) • comparison ("as", "like", "as well as", etc.), • time ("when", "while", "since", etc.) • place ("whereby", "whereupon", etc.)
Modalities (adverbs or adverbial phrases)	Enable speakers to involve themselves in what they say, or to locate what they say in time and space, through concepts of: • time ("now", "yesterday", "tomorrow", etc.) • place ("there", "here", "below", etc.) • manner ("directly", "together", etc.) • assertion ("absolutely", "certainly", etc.) • doubt ("maybe", "probably", etc.) • negation ("not", "never", "nothing", etc.) • intensity ("very", "much", "strongly", etc.)
Qualifying adjectives	• objective, i.e. describing beings or objects, regardless of the speaker's standpoint (color adjectives, for example) • subjective, i.e. indicating judgment on something or on somebody, thus enabling expression of the speaker's standpoint ("beautiful", "small", "nice", etc.) • or numeral, i.e. grouping together numbers (in letters or in figures), along with ordinal and cardinal adjectives
Personal pronouns	• in person ("i", "you", "he", etc.) • in number ("they", "we", etc.)

As examples, and broadly speaking:

- time and place connectors and modalities provide the means to locate the action
- intensity and negation modalities provide the means to dramatize the discourse
- cause and condition connectors provide the means to construct a chain of reasoning
- addition connectors provide the means to enumerate facts or characteristics
- opposition connectors more specifically provide the means to argue, to put things into perspective and to set out conflicting standpoints

In the next section, the exact method employed to examine the relationship between student ODF discourse and instructor-assessed student learning performance outcome is described.

4. METHOD AND RESEARCH APPROACH

Since no previous studies dealing with the semantic analysis of ODF discourse was found, and because categories are derived from the data itself, the approach was inductive. Frequent word categories were obtained by comparing the distribution of the occurrence frequency of the categories observed in the text with linguistic production norms. The process was summative by nature, as was the statistical approaches employed.

4.1 Research setting

Participants included students enrolled in a web-based, introductory and portfolio-driven extra-curricular short course (HEQF Level 5, 12 credits) presented over a semester within a prominent open distance learning (ODL) institution. The learning performance outcome was to demonstrate competence in the use of a programming language by coding a fully functional and modular web-based application (known as the portfolio), and which replaced a formal sit-down examination. A total of 44 students registered for the course, of which 24 students (54.5%) submitted a portfolio for final grading - the latter total representing the final sample size this study reports on.

It is acknowledged that the small sample size presents a potential research limitation where findings cannot be generalized to the broader community, and where it is acknowledged that the performance of a few individuals can have a big effect on the data. Conversely, any significant relationships found with a small sample may point at potential benefits with a larger sample and underscores the merit of the current research approach. Also, as preliminary research, there was no intention to generalise.

Approval for the study was obtained from the institutional review board on ethics. Voluntary consent to use grade marks in statistical procedures was requested and received from students. To ensure anonymity, no personal student information or marks are reported. In place of the latter, a ranking system was employed.

In presenting the course to distance students, an ODF was employed as the primary means of presentation, communication

and support between the instructor and the students, and students and students. In pursuit of a collaborative-constructivist environment, the roles of the instructor mirrored the primary teaching presence responsibilities as described by Garrison, Cleveland-Innes and Fung [10]:

- establishing curriculum content, learning activities, and timelines
- monitoring and managing purposeful collaboration and reflection
- ensuring that the community reaches the intended learning outcomes by diagnosing needs and providing timely information and direction

In ensuring that the intended learning performance outcomes are achieved, students were required to:

- report their progress and problems/issues in completing self-study tutorial units
- report problems/issues in constructing new knowledge en route to completing the practical portfolio
- provide evidence of their efforts to find solutions.
- contribute new knowledge where appropriate
- support fellow students in finding solutions to problems/issues raised

4.2 Data sources, design and methodology

Two primary data sources were used. The first data source was the word categories and subcategory statistics as extracted and calculated by Tropes. Here the primary unit of analysis was each student's total messages as text and as extracted from the ODF-database with a Structured Query Language (SQL) query that was specific to the ODF-software (Phorum – www.phorum.org) used. The results were displayed in a web page, from where it was copied and pasted into separate text files, each saved with the student number.

The second data source was the instructor-assessed student learning performance outcome data. Students were provided with a scoring rubric which stated in detail the exact portfolio requirements. The instructor-assessed practical portfolio mark (PPM) was converted to a percentage which was used to rank students.

Descriptive statics and correlation methods were then employed to interpret, evaluate and deploy the extent of the relationship between the two primary data sources.

5. RESULTS

5.1 Raw data files

Each student's ODF discourse text file was imported into Tropes with the purpose to extract semantic meta-categories that group verbs, adjectives, adverbs, personal pronouns and conjunctions. Table 2 lists the raw data files per word category and subcategory that was subjected to further statistical tests. Table rows are presented in descending order with student 1 having received the highest and student 24 the lowest PPM.

Table 2. Raw data files (Verbs word category)

VERBS					
RNK	REF	PER	STAT	FAC	TOT
1	114	0	0	0	**114**
2	245	0	0	0	**245**
3	4	0	0	9	**13**
3	35	0	0	0	**35**
3	143	0	0	0	**143**
6	87	0	0	0	**87**
7	11	0	0	0	**11**
7	105	4	0	0	**109**
9	56	0	0	0	**56**
10	54	3	0	0	**57**
11	205	11	0	0	**216**
12	0	0	4	0	**4**
12	7	0	12	0	**19**
12	10	0	0	0	**10**
12	12	0	17	0	**29**
16	24	0	0	50	**74**
17	82	0	0	0	**82**
18	0	0	64	0	**64**
19	161	7	0	0	**168**
20	0	0	17	19	**36**
21	0	0	38	50	**88**
22	0	0	0	0	**0**
23	85	0	155	0	**240**
24	6	4	0	0	**10**

Key: RNK=Student rank; REF=Reflexive; PER=Performative; STAT=Static; FAC=Factive; TOT=Total per word category.

Table 2. Raw data files continued (Connectors word category)

CONNECTORS									
RNK	CON	ADD	CAU	DIS	GOA	OPP	COM	TIM	TOT
1	27	0	0	13	0	0	19	18	**77**
2	55	0	0	0	8	43	34	27	**167**
3	0	0	0	0	0	0	0	0	**0**
3	14	0	6	0	0	0	8	11	**39**
3	30	0	0	14	3	0	18	13	**78**
6	25	0	22	11	3	0	15	10	**86**
7	3	0	3	0	0	0	0	0	**6**
7	21	0	0	6	0	0	0	17	**44**
9	18	0	0	0	0	0	7	3	**28**
10	9	0	5	4	0	0	0	7	**25**
11	35	0	0	15	0	0	0	19	**69**
12	0	0	0	0	0	0	0	0	**0**
12	7	0	0	0	0	0	0	0	**7**
12	0	0	0	0	0	0	0	0	**0**
12	0	12	0	0	0	0	0	0	**12**
16	7	0	0	0	0	0	5	0	**12**
17	11	0	11	8	0	0	0	16	**46**
18	0	0	0	0	0	6	0	8	**14**
19	51	0	0	0	0	0	24	11	**86**
20	0	0	0	0	0	0	0	3	**3**
21	3	0	3	0	0	0	0	0	**6**
22	0	0	0	0	0	0	0	0	**0**
23	25	0	0	0	0	18	19	0	**62**
24	0	6	0	0	0	0	0	0	**6**

Table 2. Raw data files continued (Modalities word category)

MODALITIES								
RNK	**TIM**	**PLA**	**MAN**	**DOU**	**INT**	**NEG**	**ASS**	**TOT**
1	26	0	36	4	0	0	0	**66**
2	69	0	102	0	0	0	35	**206**
3	0	0	4	0	0	0	0	**4**
3	27	0	8	0	0	0	0	**35**
3	39	29	33	0	0	32	0	**133**
6	23	0	32	0	0	0	0	**55**
7	4	4	5	0	0	4	0	**17**
7	37	0	18	0	0	0	0	**55**
9	0	0	22	0	0	12	0	**34**
10	22	12	19	0	0	0	0	**53**
11	47	41	55	3	0	0	20	**166**
12	0	0	0	0	0	0	0	**0**
12	3	0	3	0	0	0	0	**6**
12	0	0	0	0	0	0	0	**0**
12	5	3	0	0	0	4	0	**12**
16	0	0	0	0	0	0	0	**0**
17	13	14	22	0	0	0	0	**49**
18	0	11	9	0	0	0	0	**20**
19	41	0	53	0	0	0	0	**94**
20	0	0	0	0	0	0	0	**0**
21	0	6	6	0	0	7	0	**19**
22	0	0	0	0	0	0	0	**0**
23	16	0	32	0	4	0	9	**61**
24	0	0	0	0	0	0	0	**0**

Key: RNK=Student rank; CON=Condition; ADD=Addition; CAU=Cause; DIS=Disjunction; GOA=Goal; OPP=Opposition; COM=Comparison; TIME=Time, TOT=Total per word category.

Table 2. Raw data files continued (Adjectives word category and all word categories)

ADJECTIVES			
RNK	**OBJ**	**NUM**	**TOT**
1	103	39	**142**
2	193	0	**193**
3	0	33	**33**
3	64	28	**92**
3	253	137	**390**
6	115	0	**115**
7	16	5	**21**
7	72	25	**97**
9	65	0	**65**
10	47	0	**47**
11	197	53	**250**
12	4	0	**4**
12	0	13	**13**
12	13	0	**13**
12	15	8	**23**
16	34	0	**34**
17	0	0	**0**
18	34	16	**50**
19	175	89	**264**
20	10	5	**15**
21	23	0	**23**
22	0	0	**0**
23	98	44	**142**
24	9	4	**13**

ALL WORD CATEGORIES	
RNK	**GRANDTOTAL**
1	895
2	1883
3	104
3	434
3	1600
6	793
7	123
7	686
9	392
10	434
11	1585
12	19
12	95
12	49
12	170
16	272
17	431
18	344
19	1404
20	122
21	299
22	0
23	1123
24	68

Key: RNK=Student rank; OBJ=Objective; NUM=Numeral; TOT=Total per word category.

A total of 3837 subcategory counts were extracted from 743 messages posted by the 24 students. In setting the context, the following cursory observations are made:

- the instructor contributed 179 messages, which may have influenced the content of students' messages
- these inputs are considered a constant, i.e. all students were exposed to the instructor's presence
- zero counts were not discarded, as these are considered a "result" i.e. limited or no use of modalities are suggestive of limited collaboration
- comparing the total modalities counts of the top 11 ranked students against the bottom 13, it is evident that the former group used more adverbs or adverbial phrases
- three (3) students had a grand total of more than a 1500 subcategory counts, 2 more than 1000, 4 more than 500, 9 more than 100 and the rest (6) less than 100
- the highest number of messages posted by a single student was 116 and the lowest 3
- no discernible pattern is readily evident, other than that the first subcategory column counts per word category tends to contain the highest number of counts for that word category

A next approach was to generate a raw data file that reflects the influential Community of Inquiry (CoI) framework categories of Social Presence, Cognitive Presence or Teaching Presence. Using the Reference analysis tool of Tropes, closely related common and proper nouns that were identified in the combined ODF discourse were dragged into the Scenario tool and categorized under a Social Presence class, a Cognitive Presence class or a Teaching Presence class. For example, the word "Hi" and it semantic equivalents, of which there were 168 occurrences, were grouped under the Social Presence class. Similarly, the word "use" was grouped under Teaching presence. The raw data file generated is presented in Table 3. With a total count of 2996, the raw data suggests that the ODF community was overwhelmingly cognitively-orientated.

Table 3. Community of Inquiry raw data file

RNK	**CP**	**SP**	**TP**	**TOT**
1	240	33	16	**289**
2	435	72	34	**541**
3	8	0	0	**8**
4	118	18	10	**146**
5	472	33	80	**585**
6	182	21	18	**221**
7	17	8	0	**25**
8	193	18	15	**226**
9	81	12	11	**104**
10	3	7	6	**16**
11	350	72	28	**450**
12	0	0	0	**0**
13	22	0	0	**22**
14	46	4	0	**50**
15	14	4	0	**18**
16	393	100	24	**517**
17	33	7	3	**43**
18	45	5	6	**56**
19	151	8	32	**191**
20	16	3	0	**19**
21	3	3	0	**6**
22	29	28	6	**63**
23	140	79	12	**231**
24	5	5	0	**10**
TOT	**2996**	**540**	**301**	**3837**

Key: CP=Cognitive Presence; SP=Social Presence; TP=Teaching Presence

5.2 Results

Before the raw data files were subjected to statistical tests, the word categories were tested for reliability using Cronbach's alpha (Table 4). The Verb, Modalities, Adjectives and Pronouns categories returned acceptable internal consistencies (> 0.7). The Connecters and CoI categories, however, returned unacceptable values and were therefore not subjected to any further statistical analysis.

Table 4. Cronbach's alpha values

Category	Cronbach's Alpha	n Items
Verbs	.924	4
Connectors	.194	8
Modalities	.753	7
Adjectives	.707	2
Pronouns	.710	4
CoI	.501	3

Descriptive statistics

Table 5 lists the mean, median and mode reported for each of the word subcategories.

The highest means reported were for the Adjectives word category (grand mean = 56.63) followed by the Verbs (31.84), Pronouns (25.18) and Modalities categories (11.29).

Table 5. Word subcategory means, medians and modes

Cat	Subcat	N		Mean	Median	Mode	Std. Devi.	Min	Max
		Valid	Missing						
VERBS	REF	24	0	60.25	29.5	0	70.758	0	245
	PER	24	0	1.20	0	0	2.765	0	11
	STA	24	0	12.79	0	0	33.864	0	155
	FAC	24	0	79.58	0	0	14.384	0	50
	TOT	24	0	5.38	60.5	0	74.614	0	245
MODALITIES	TIM	24	0	15.5	4.5	0	19.413	0	69
	PLA	24	0	5	0	0	10.308	0	41
	MAN	24	0	19.12	8.5	0	24.474	0	102
	DOU	24	0	0.29	0	0	0.999	0	4
	INT	24	0	0.16	0	0	0.816	0	4
	NEG	24	0	2.45	0	0	6.928	0	32
	ASS	24	0	2.66	0	0	8.170	0	35
	TOT	24	0	45.20	27	0	55.366	0	206
ADJ	OB	24	0	64.16	34	0	73.639	0	253
	NUM	24	0	20.79	5	0	33.384	0	137
	TOT	24	0	84.95	40.5	13	100.686	0	390
PRONOUN	I	24	0	40.33	19	94	46.143	0	180
	WE	24	0	2.04	0	0	4.037	0	12
	YOU	24	0	19.54	8	0	25.083	00	81
	THEY	24	0	1.04	0	0	3.883	0	18
	TOT	24	0	62.95	32	32	68.067	0	261

Key: RNK=Student rank; REF=Reflexive; PER=Performative; STAT=Static; FAC=Factive; CON=Condition; ADD=Addition,; CAU=Cause; DIS=Disjunction; GOA=Goal; OPP=Opposition; COM=Comparison; TIM=Time, PLA=Place; MAN=Manner; DOU=Doubt; INT=Intensity; NEG=Negation; ASS=Assert; OBJ=Objective; NUM=Numeral; TOT=Total per word category.

Correlations

In order to extract more meaningful results, the next step in analyzing the data was to use correlation methods. The purpose was to investigate the strength of association between the dependent variable PPM, and independent variables (a) Verbs subcategories, (b) Modalities subcategories, (c) Adjectives subcategories, (d) Pronoun subcategories and (e) Grand Total of all word group subcategories. Because the sample size was less than 50, the normality of each variable was first computed using the Shapiro-Wilk test. Most of the variables were not normally distributed ($p < 0.05$), indicating that non-parametric correlations using Spearman's Rho was required.

The results are presented in Table 5.

Significant (*: $p < 0.05$, **: $p < 0.02$ and ***: $p < 0.01$) correlations were reported for:

- Verbs word category$_{ref}$ (r_s =0.496, p= 0.013) **
- Verbs word category$_{sta}$ (r_s = 0.502, p= 0.012)*
- Connectors word category$_{dis}$ (r_s = 0.426, p= 0.381)*
- Connectors word category$_{goa}$ (r_s = 0.469, p= 0.020)*
- Connectors word category$_{tim}$ (r_s = 0.508,1 p= 0.011)***
- Modalities word category$_{tim}$ (r_s = 0.506, p= 0.011)**
- Modalities word category$_{man}$ (r_s = 0.431, p= 0.035)*
- Modalities word category$_{tot}$ (r_s = 0.457, p= 0.248)*
- Adjectives word category$_{tot}$ (r_s = 0.464, p= 0.022)*
- Pronouns word category$_{you}$ (r_s = 0.424, p= 0.039)*
- Grand Total of all subcategories (r_s = 0.416, p= 0.043)*

Table 5. Correlations between PPM and Word subcategories and Grand Total of all Word subcategories

VERBS	REF	0.496**	0.0137
	PER	0.139	0.5166
	STA	0.502*	0.0125
	FAC	0.206	0.335
	TOT	0.203	0.3412
CONNECTORS	CON	0.44	0.0314
	ADD	0.263	0.2138
	CAU	0.153	0.474
	DIS	0.426*	0.381
	GOA	0.469*	0.02
	OPP	0.076	0.724
	COM	0.347	0.096
	TIM	0.508***	0.011
	TOT	0.385	0.062

MODALITIES	TIM	0.506**	0.011
	PLA	0.004	0.9865
	MAN	0.431*	0.035
	DOU	0.293	0.164
	INT	0.317	0.13
	NEG	0.128	549
	ASS	0.059	0.783
	TOT	0.457*	0.248
ADJ	OB	0.42	41
	NUM	0.176	0.41
	TOT	0.464*	0.022
PRONOUNS	I	0.206	0.335
	WE	0.257	0.224
	YOU	0.424*	0.039
	THEY	0.235	0.269
	TOT	0.264	0.211
GT	TOT	0.416*	0.043

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.02 level (2-tailed)
*** Correlation is significant at the 0.01 level (2-tailed)
Key: RNK=Student rank; REF=Reflexive; PER=Performative; STAT=Static; FAC=Factive; CON=Condition; ADD=Addition,; CAU=Cause; DIS=Disjunction; GOA=Goal; OPP=Opposition; COM=Comparison; TIM=Time, PLA=Place; MAN=Manner; DOU=Doubt; INT=Intensity; NEG=Negation; ASS=Assert; OBJ=Objective; NUM=Numeral; TOT=Total per word category; GT= Grand total of all word subcategories.

Summarized, strong and positive correlations were found between the PPM and two of the Verbs subcategories, three of the Connectors subcategories, two of the Modalities subcategories, as well as the Modalities category Total, the Adjectives category total, one Pronouns subcategory and the Grand Total.

Specific and significant subcategories that contributed to the PPM were: Reflexive and Static Verbs; Disjunctive, Goal and Time Connectors; Time, Manner and Total number of Modalities; the Total number of Adjectives (I, we, you, they); and the Grand Total of all subcategories per student. Although having the lowest r_s coefficient value, the significance of the Grand Total of all word categories per student stands out.

6. DISCUSSION AND CONCLUSION

The main purpose of this paper was to document the author's first effort in using automated Language Processing and Semantic Classification software to examine the relationship between student ODF discourse in a web-based course where the ODF was central to the teaching and learning strategy, and instructor-assessed student learning performance outcome.

The research results reported are encouraging. Significant and strong positive correlations were reported for 11 (42%) of the 26 possible word categories, two (50%) of the word category totals, and for the grand total of all word categories. As acknowledged in the methods and research approach section, the small sample size presents a potential research limitation where the reported findings cannot be generalized to the broader community. However, in using acceptable non-parametric test protocols when N=small, a striking effect where results were statistically different from zero (in some instances at the $p < 0.001$ level) was observed.

The results of this study are perhaps best disseminated by considering further research opportunities. As pointed out, Tropes offers many other analyses approaches such as stylistic/rhetorical (argumentative, enunciative, descriptive or narrative style), thematic (reference fields), as well as detection of discursive/chronological structures. However, it is the option to create personalized and own specification scenarios that may well hold the most promise. Such an approach will require the development and establishment of a general and/or course-specific educational discourse lexicon/s. Here two suggestions are forwarded. Given the amount of research already done in this area, the lexemes should fit within the Community of Inquiry's framework of teaching, social and cognitive presences. Also, as the current results suggest, student learning performance outcomes should drive the process of validating the lexicon/s.

In conclusion, the results achieved not only underscore the potential usefulness and value of automated Language Processing and Semantic Classification software to reliably deal with educational discourse, but would greatly simplify the act of discourse analysis – especially when larger ODL online courses are of interest. Most important is that the human factor is eliminated from the analysis process, thereby ensuring that the results achieved will always be valid.

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Problem-Solving Ability of First Year CS Students: A Case Study and Intervention

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ABSTRACT
This paper reports the findings of computational thinking research undertaken to develop problem-solving skills in first year computer science students. Through the use of preand post-tests, statistical results are presented showing the definite acquisition of problem-solving skills by the students after completing the introductory first year computer science course. These skills are argued to be both innate in some students and acquired in others. By identifying the component skills required and presenting a step-by-step approach to teaching problem solving, this research aims to provide a method for actively instilling these skills in learners who lack them.

Categories and Subject Descriptors
Social and professional topics [Computing education]: [computational thinking]

Keywords
Computational Thinking, Problem-Solving, Case Study

1. INTRODUCTION
This research reports the findings of research undertaken in the field of computational thinking (CT) in the Department of Computer Science (CS) at Rhodes University (RU) in South Africa. This research is primarily concerned with the problem-solving ability of CS101 students, including both students intending to major in CS and those concerned with obtaining only a few credits in CS.

This study comprises on-going research within this field and seeks to further the initiatives started by Gouws, Bradshaw, & Wentworth [6]. This is achieved by acknowledging past findings as well as adapting to meet new challenges as they are identified.

The efforts of the current CT researchers at RU are focused on developing a codified approach to problem-solving; one that can easily be replicated and described in a step-by-step manner to a non-computer scientist.

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2. PURPOSE AND METHODOLOGY
This paper seeks to report the experiences and findings of the authors related to CT skills within the context of undergraduate CS1 students at RU. Therefore, the authors have chosen to report their findings in the form of a case study. Yin [18, p. 18] describes a case study as a means to "understand a real-life phenomenon in depth, but such understanding encompasse[s] important contextual conditions." A critical component of a case study according to Yin is the reporting thereof.

The guidelines described by Creswell [1, p. 195-196] recommend the following structure for reporting a case study:

1. Entry vignette
2. Purpose and methodology
3. Context of the study
4. Identification of issues
5. Further descriptions of key issues
6. Assertions
7. Closing vignette

This paper is structured to mimic these guidelines.

3. CONTEXT
Since Wing [17] initiated a global discussion on the promotion of CT as a fundamental skill for the 21st century, much progress has been made by researchers. There is a wealth of knowledge targeting both secondary school learners [2, 7] and university undergraduates [8, 16, 14, 12].

There is common agreement on the importance of CT globally. However, despite this agreement, there remains much discussion on the formal definition of CT. Many authors place emphasis on the importance of programming as a skill, while others prefer to focus on other skills such as algorithmic thinking, or even refer back to the research conducted by Papert [13], which is reminiscent of 'constructionism'.

Many 'opponents' to the current CT movement are quick to recall the work done by Papert and call for a more modest view of the importance of CT and CS. One such opponent is Denning [3] who reminds us that CT is but one single aspect of CS, which does not reflect the entire field of study adequately.

CT is another paradigm of thought to be added to the existing list alongside the likes of "Mathematical Thinking" [15], "Algorithmic Thinking" [10] and "Critical Thinking" [5].

Despite the broad definition and mild resistance, the global CT movement has reported a variety of successes [7, 11].

For the purposes of our research we accept the operational definition of CT as presented by the International Society for

Technology in Education (ISTE) [9]. This definition formulates CT as the combination of six characteristics alongside five "dispositions or attitudes". These characteristics are listed below in an abbreviated form:

1. Enabling use of a computer (to solve problems)
2. Organising and analysing data
3. Models and simulations
4. Algorithmic thinking
5. Efficiency of solutions
6. Transference of solutions

4. IDENTIFICATION OF ISSUES

As an on-going longitudinal study since 2013, a CT test has been administered to first year CS students at RU at the start of the academic year and again six months later. These tests form preand post-tests for students who have enrolled in CS101, which is the first semester foundation course for students majoring in CS.

The basis for this research is the work initiated by Gouws, Bradshaw, & Wentworth [6]. Their initial CT test of 25 questions was refined and re-presented in the 2014 academic year to the next CS101 class.

As in the first year of this study, the pre-test in 2014 was administered at the start of the CS101 course, prior to any formal university instruction. The post-test was administered after the students had completed the CS101 course.

The content of these tests was structured to test general problem-solving skills (which in the context of CS form the core of CT) and not programming. This was done to ensure that students without prior exposure to programming (or CS) were still able to achieve good results if they possessed the required problem-solving skills.

Thus, our CT test is more concerned with the computational context in which the students operate than the inherent coding ability of students. In other words, we are aiming explicitly at "problem-solving" as opposed to "program-solving". Thus, despite our goals differing from many other similar research initiatives, they are still firmly seated in the field of CT.

5. DESCRIPTION OF KEY ISSUES

This study is chiefly concerned with the findings of the 2014 and 2015 (thus far) academic years. The data collected during this time are presented here, together with analyses thereof.

5.1 2014 Computational Thinking Test

As in 2013, a pre-test was administered to the CS101 students; this test was a revised version of the original 25 questions. The changes made were of an editorial nature; certain questions were reworded to clarify the problem and remove any form of ambiguity.

The post-test was administered to the CS101 students at the commencement of the second semester. The questions in this test differed slightly from those in the pre-test to ensure that students were not relying on memorised answers. (However, it should be noted, that at no stage were answers provided to the students, and neither were they allowed to retain the question papers used in the pre-test.) Many of the variable values in the questions were adjusted to produce new questions, which were logically identical to the set of questions in the pre-test.

Table 1: Significant paired *t*-test results (N = 45)

(Significance: * 5% level; ** 1% level; *** 0.1% level)

Question no.	p-value
1	0.005**
5	0.041*
10	0.009**
13	0.009**
19	0.015*
22	<0.001***
23	0.010*
24	0.001**
25	0.035*

By analysing individual student's answers to these two test, we were able to measure the change in a student's ability to solve problems. We observed a marked increase in post-test scores compared with the pre-test. Based on the results of statistical tests, we reduced the question set to those questions that were more indicative of the change we wished to study.

5.2 2014 Statistical Results

In 2014, the pre-test was completed by 85 students, while the post-test was completed by 45 students. The difference in the number of students is due to a number of factors; some students drop out during the first semester, while others do not register for the second semester at all, i.e., they only pursue a single CS module. For the purposes of this research only those students who had completed both tests were considered (N = 45).

The overall mean scores for the pre- and post-tests were 50% and 58%, respectively. The statistical software package R was used to analyse the overall results of the two tests and ascertain the significance of the results. Based on the results of a one-sided paired Student's t-test, the improvement in the overall test scores is significant at the 0.1% level ($p < 0.001$). From this significant positive shift in mean values, we deduce that there are observable skill acquisitions within the CS101 course, which are inherently related to learning programming, but which can also exist prior to any instruction.

These results were further analysed by means of a paired Student's t-test on a per question basis, which enabled questions to be filtered to identify those with significant p-values. Of the 25 questions, nine had significant p-values at a 5% (or lower) level of significance as summarised in Table 1.

Of these nine questions, four were found to be significant at the 1% significance level and one was significant at the

0.1% level. Based on the results of the statistical tests, these nine questions formed the basis of our 2015 CT pretest.

Figures 1 and 2 show the cumulative marks achieved by students for the pre- and post-tests respectively, based on the marks obtained for the indicative questions. These figures show that a significant portion of students achieve less than 60% for the pre-test, whereas the post-test has a 'spike' of students achieving 70%. These distributions are evident in the curves of the graphs.

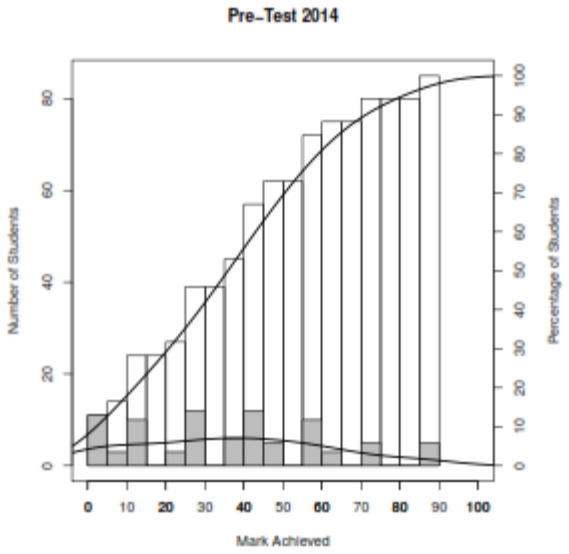

Figure 1: Cumulative marks for 2014 pre-test (*N* = 85)

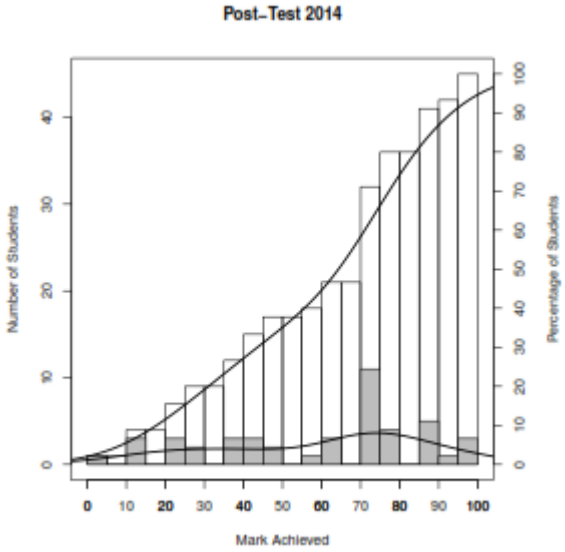

Figure 2: Cumulative marks for 2014 post-test (*N* = 45)

5.3 Question Analysis

The nine questions identified above are the most significant of an improvement in the problem-solving ability of the students tested. This is significant as the skills tested in these questions do not explicitly form part of the CS101 curriculum, but are ancillary to programming. That is, the process of learning to solve problems through programming has improved the students' general problem-solving ability, which, given the nature of programming, is intuitive.

The nine significant questions were analysed according to the operational definition of CT. The analysis is presented in Table 2 and is subject to the authors' interpretation of how the questions may be solved. Those skills important to our purpose of improving problem-solving ability are discussed in more detail below.

Table 2: Question-characteristic breakdown

Characteristics	Questions
Enabling use of a computer	1, 10, 24, 25
Organising and analysing data	1, 10
Models and simulations	1, 10, 19, 23
Algorithmic thinking	5, 19, 22, 24, 25
Efficiency of solutions	13, 22, 24, 25
Transference of solutions	13

5.3.1 Algorithmic Thinking

This characteristic features in five of the nine questions and forms the core of problem-solving. It represents a student's ability to solve a problem by using a series of ordered steps.

Questions 24 and 25 require a student to write down an optimal set of steps to draw a specific shape and to navigate a robot along a path, respectively. Both of these questions require students to develop and describe a set of specific instructions to be followed in a prescribed order, which is precisely the definition of an algorithm.

5.3.2 Models and Simulations

Four of the nine questions exhibit this characteristic, which represents the ability to manipulate data through the use of models and abstractions. This characteristic enables a student to work with more complex systems by simplifying the system.

Question 1 describes folding a piece of paper a number of times and calculating its thickness. The student needs to simulate this folding mentally to determine how many layers the folded piece of paper will have, and thus, this question falls in the "Modelling and simulations" category. This question also requires the student to work with numbers that are not intuitive in a mental model, such as thickness measuring less than half a millimetre or the number of layers in the hundreds. This is especially true for students with less developed mathematical skills, and hence, this question including the characteristic of "Enabling use of a computer".

5.3.3 Efficiency of Solutions

Four of the nine questions include the efficiency characteristic. Students are required to question "how good" their solutions are; that is, not only must students solve the problem, but they should also attempt to optimise their solutions. For example, Question 22 involves finding the shortest path between two points within a weighted network of connected nodes; this is easily solved by Dijkstra's algorithm [4]. Therefore, this question was categorised as including both "Algorithmic thinking" and "Efficiency of solutions". The latter refers to the emphasis of finding the path that is the most efficient within the network.

5.3.4 Other Characteristics

The remaining three characteristics are no less important within the context of CT, but within this research, they were found to be less indicative of a student's latent problem-solving ability. For example, Question 13 involves manipulating predetermined weights in order to weigh an item, something with which students can easily identify, since it is analogous to calculating change at a cash store. Thus, we classify this question as involving both "Efficiency of solutions" and "Transference of solutions". "Enabling use of a computer" is not considered important as we are specifically focusing on manual skills.

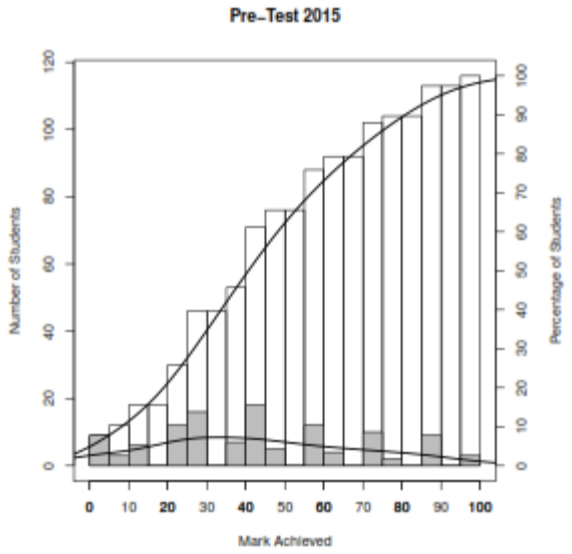

Figure 3: Cumulative marks for 2015 pre-test (*N* = 116)

5.4 2015 Computational Thinking Test

As a continuation of the on-going longitudinal approach of this research, the CT test was administered at the start of the 2015 academic year. As mentioned previously, this was the first time that the test was significantly altered. The questions in this test are the nine questions that were identified to be significant indicators in 2014. (One extra question was added to 'round out' the number of test questions.)

Figure 3 shows the marks achieved for the 2015 pre-test; as before, only the marks obtained for the indicative questions are included. The reader will notice the similarity of this graph to that of the 2014 pre-test (Figure 1).

Using the overall scores for the 2015 pre-test we have identified students with less developed problem-solving abilities.

6. ASSERTIONS

Based on the findings described above, three components have been developed to further the research goal of developing a codified approach to problem-solving, namely, a set of required problem-solving skills, an approach to employing these skills, and a means to impart these skills to students. These components are described below.

6.1 Problem-Solving Skills

From the characteristics described above, we have developed the following list of skills which we believe form the core skills associated with problem-solving in the context of CT: analytic, communicative, completeness, computative, confidence, evaluative, focus, inventive, linguistic, logic, numeric, optimisation, ordering, organisation, planning, predictive, recollection, rigour, and simplification.

These skills can be grouped into categories which align with the characteristics (described in the operational definition of CT) that they support:

Algorithmic skills: analytic, computative, evaluative, inventive, logic, numeric, optimisation, ordering, planning, predictive, and simplification.

Models and simulations: analytic, computative, ordering, organisation, planning, rigour, and simplification.

Efficiency of solutions: analytic, computative, evaluative, focus, inventive, logic, numeric, optimisation, organisation, planning, predictive, and rigour.

Other characteristics: communicative, confidence, inventive, linguistic, organisation, recollection, and rigour.

The interpretation of these skills is based on their standard definitions; where applicable, specific/alternative interpretations are provided in the approach described below.

6.2 Problem-Solving Approach

Based on the general operational definition of CT adopted, and the skills previously identified in this research, we have developed an approach designed to teach problem-solving. The key steps in this approach are listed below:

1. Achieve a clear state of mind
2. Aim to understand the problem thoroughly
3. Examine the problem critically
4. Simplify the problem based on an envisaged solution
5. Identify a possible route to the solution
6. Be confident that the problem can be solved

Each of these steps forms a component in our "waterfall model of problem-solving" as depicted in Figure 4.

When navigating the waterfall, the process is iterative in nature; one starts at the top (*Clear Mind*) and proceeds to follow the downward arrows as depicted. Ideally, the problem would be solved (or would be close to being solved) on reaching the bottom (*Solve*). However, it is possible to return to a previous step or restart the process entirely, by following the upward arrows. However, restarting should not be viewed as failure to solve the problem; often more information is available in a new iteration than in the initial attempt owing to the increased understanding of the problem, or an entirely new 'path' to the solution becomes evident during a subsequent pass down the waterfall. Finally, the *Be Confident* component is pervasive throughout the entire problem-solving process, irrespective of how many arrows are followed.

6.2.1 Achieve a clear state of mind

Many humans' immediate reaction when encountering a difficult problem to solve, is to panic. The first step in our approach encourages the problem-solvers to inhale deeply and to relax. This will help calm their thoughts and allow them to think rationally as opposed to immediately abandoning any attempts to solve the problem. This step encompasses the skills of confidence, organisation, planning, and rigour. These skills reflect the desired state of mind of the student when first approaching a problem. In this step, rigour refers to the students' ability to face the challenge; in the face of an unknown problem, they should learn not to capitulate.

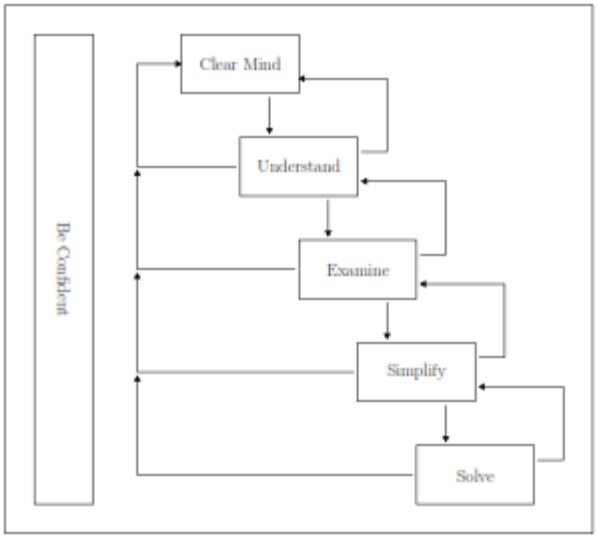

Figure 4: Waterfall model of problem-solving

6.2.2 Aim to understand the problem thoroughly

At this point we expect the problem-solvers to be thinking more clearly. We ask them to re-read the entire problem description. A mistake many make is to 'skim' the problem description and not focus on the actual description presented to them. Problem-solvers are asked to focus on comprehending the question at hand.

A common technique used by successful problem-solvers is to highlight or underline keywords within the problem description; we encourage novice problem-solvers to do this. What we are aiming for in this step is an in-depth understanding of the problem description, as this is vital to finding a solution.

This step is associated with the following skills: analytic, completeness, evaluative, linguistic, logic, and rigour. These skills describe how the problem-solver must thoroughly evaluate the problem description, for instance; the linguistic skill refers to the ability to comprehend the meaning of the words within the description, and rigour now refers to how the problem-solvers should not skip over portions of the description.

6.2.3 Examine the problem critically

At this point, problem-solvers may think that they can solve the problem. Here we test this belief in a constructive manner.

One way of doing this is to ask the problem-solver to re-write the problem statement in his/her own words; this will highlight missing information. Analogies can also be used to help develop mental models of the problem at hand.

The problem-solver must also be able to identify the point at which the problem is solved, as well as having an idea of what it may take to reach this point. In other words, s/he must build a roadmap of how s/he intends solving the problem.

After completing this step, students should have created a "silhouette of the solution" in their minds. In other words, they can describe the nature of the solution without describing its details. For students to complete this step they must exhibit the following skills: analytic, communicative, completeness, evaluation, inventive, linguistic, organisation, planning, and simplification. These skills form the basis of building a mental model, organisation and planning skills help problem-solvers 'lay out' the components of the problem in their minds.

6.2.4 Simplify problem based on envisaged solution

Some problems are inherently complex and the problem- solvers will need to produce an effective algorithm to solve them. These algorithms may stretch beyond the problem- solvers' experience and expertise. Students will need to develop 'foundations' of knowledge to tackle these problems.

Attempting to brute-force many problems often yields a result, but at the expense of much wasted time. Conversely, a small amount of time invested in smaller sub- problems can drastically simplify a problem. This is often the point at which a question may 'trick' the student, if the student identifies the 'trick', the complexity of the problem can be reduced drastically.

This step involves the following skills: computative, evaluative, inventive, logic, numeric, optimisation, organisation, predictive, rigour, and simplification. Logic skills help the problem-solvers identify where portions of the problem can be broken apart, while prediction skills help them decide if they can piece it back together at a later stage.

6.2.5 Identify a possible route to the solution

Applying the Pareto principle[1] (80/20 rule), problem-solvers may find that a small amount of work invested in answering a specific part of a problem will help solve most of the greater problem. They can then re-evaluate the possible solutions available to them.

Problem-solvers will need to develop a solution based on their previous experience. This past experience will become the tool-set of skills that they can apply to solve the problem. Problem-solvers may also need to recount their first principles or elemental rules. Doing so, they can begin to construct their own mental models, which will eventually allow them to develop (and describe) a viable solution.

This step is the most difficult to teach, as it requires the students to think about the solution creatively. This step is the culmination of the steps leading up to it, representing the final hurdle for problem-solvers to cross in the problem-solving process.

The following skills are required for this step: analytic, computative, evaluation, inventive, logic, numeric, optimization, ordering, planning, predictive, rigour, and simplification. Evaluative, predictive, and recollection skills all are required to determine if a previous proof or example may help solve the problem. Analytic and computative skills will help quantify the amount of work required for each step.

6.2.6 Be confident that the problem can be solved

Hesitation to answer a question is a not uncommon response amongst problem-solvers, specifically, students may fear the mockery of their instructors and peers, and would rather not answer a question than answer incorrectly. This is a major hurdle that must be overcome, but may also be inherent within the environment in which the problem-solver is engaged. Fostering trust may be important at this point. Alternatively, it may be possible to excite the problem-solver to a state of curiosity to find the solution.

In the end, a large portion of problem-solving is trial and error; this must be conveyed to the problem-solvers. This step reinforces

[1] http://www.investopedia.com/terms/p/paretoprinciple.asp

the skills of the first step, namely: confidence, organisation, planning, and rigour.

The problem-solvers are encouraged to apply these skills throughout the problem-solving problem-process; that is, this step reflects the overarching state of mind that they should adopt.

6.3 Problem-Solving Intervention

At the time of writing, this intervention is still underway and as such, results are not yet available for meaningful reporting. Results will however, be available by June

2015.

6.3.1 2015 Problem-Solving Intervention

The third component of the CT research conducted at RU is the intervention, which takes the form of a workshop program designed to encourage students to develop the identified problem-solving skills. The workshop is open to a subset of the students who failed to achieve good results in the 2015 CT pre-test (N = 50). This group, despite not being selected under ideal random conditions, forms the "treated group" for our statistical purposes. Their performance will be compared with the "control group" (consisting of those who performed poorly in the the 2015 pre-test, but who did not participate in the intervention) and with the remainder of the CS1 class.

The workshop is designed to achieve two goals:

- Encourage students to engage in problem-solving tasks
- Advocate the use of the problem-solving approach described above

The workshop will be run in non-class times in a relaxed setting. Students will be asked to attend a single session per week over the course of six weeks, with the duration each session being one hour. Throughout these sessions, the attitude, approaches, and progress of students will be recorded.

6.3.2 Anticipated Findings

By administering the intervention, we hope to develop a greater understanding of the approaches adopted by the selected students. We will refine the approach as necessary as well as develop new approaches as obstacles are encountered.

The expected findings of this intervention will be both quantitative and qualitative.

Quantitative results: The 2015 post-test results of the students in the intervention group will be compared with the remaining CS1 students to determine whether there are measurable changes in the problem-solving abilities of the students involved.

Qualitative results: Feedback elicited from the students involved will be recorded and reported. This feedback will take the form of both observations by the researchers (i.e., student attitudes) and an envisaged exit questionnaire.

7. CONCLUSION

Thus far, the CT research initiative at RU has contributed to advancement of CT in the form of an analysis of first year CS performance results and the subsequent development of tools and techniques designed to further future research in this field.

The CT test has been revised over the past three years and now consists of a minimal set of questions that are discriminative in determining problem-solving ability. The results of the repeated applications of this test have been consistent over the past two years, providing a solid baseline for investigating the effectiveness of the intervention presented in this paper.

The problem-solving approach presented in this paper has contributed to achieving the goal of this research, namely, to develop a codified approach to problem-solving that can be taught in a meaningful way to appropriate students. Future research will focus on validation of the skills identified, the proposed problem-solving approach, and the intervention. In 2015, this will be done through analyses of the pre- and post-tests, where the latter still needs to be administered.

By providing the tools and techniques presented in this paper, it is our aim to create a mechanical approach to problem-solving that can easily be taught in a step-by-step manner. This step-by-step process will form the basis of our future efforts to improve the appeal of CT and ultimately, CS amongst learners at all levels of the educational system.

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Investigating the Applicability of Belbin Roles on Participatory Levels in IT Student Teams

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ABSTRACT
In an attempt to improve the overall teamwork experience for our Software Engineering (SE) undergraduates, we investigated the relationship between participatory levels of team members and their Belbin roles. Previously, SE projects at undergraduate level tended to focus on the product delivered by a team more than on the team dynamics. We propose that the focus should be redirected to include team functionality. Teamwork projects should create opportunities for students to learn how to participate effectively in teams through experiential learning.

In this paper we investigate whether or not the Belbin team role theory can be applied to facilitate this. In working with the creation of teams using this theory we hope to improve the quality of teams through assisting the students to know their strengths and weaknesses and to delegate tasks to members according to their strengths. In this manner we hope to create functional teams where each student works to her strengths and avoid her weaknesses. We established the Belbin roles of each student and then investigated the participatory levels of the team members of multiple teams to which each student was assigned. We had different teams for each deliverable, which meant that the students did not work with the same people. We looked the prevalence of social loafers in each team to find out if there was any correlation between the Belbin roles and the number of social loafers. We found, using two years' worth of data that there seems to be no correlation. This can be ascribed to a number of factors which are discussed in detail. Nevertheless, we intend pursuing the study with additional data as well as investigating factors that influence teams. We recognise that there is no ideal way of creating functional teams. This research contributes to information that may ultimatly influence our teaching in ways that may enhance the quality of the teamwork and make it a positive learning experience for our students.

Categories and Subject Descriptors
D.2.9 [**Software Engineering**]: Management – Programming Teams; K.3.2 [**Computers and Education**]: Computers and Information Science Education; K.6.1 [**Management of Computing and Information Systems**]: Project and People Management – Staffing, Training

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General Terms
Management, Human Factors

Keywords
Team formation, teaching teamwork, soft skills

1. INTRODUCTION
Software Engineering (SE) projects are an integral part of Computer Science at undergraduate level, but many SE teams at undergraduate level, have difficulties for a number of reasons. Although the acquisition of teamwork skills is part of the SE projects, this aspect is often neglected in favour of the product.

In an attempt to enhance the teamwork skills, we investigated various aspects of teamwork. The idea being that if the teamwork skills can be improved, the overall experience will be enhanced. This could lead to a more positive experience of teamwork and assist students to realise that the process is as important as the product.

Tenenberg [38] proposes policies that could be put in place to enhance cooperation between members. Common self-serving behavioural patterns such as tit-for-tat as well as increased non-cooperation caused by the presence of persistent free riders is likely to be deminished through enhancing actions such as face-to-face communication, monitoring and sanctions.

Cain et al [15] emphasise that "Software development is a predominantly social activity" and reminds us that people are still the most important aspect of any SE enterprise. The success of the actions proposed by Tenenberg may be enhanced when the teams are assembled in ways that are known to be conducive to positive team experiences. For this reason we would like to establish whether the application of Belbin's team role theory supports the creation of team environments where the members are more likely to apply principles associated with eliciting cooperation.

We compared the participatory levels of the SE students in teams and the Belbin roles of those students to establish whether there is a correlation. The participatory levels are established through self and peer assessment of the team members.

To identify the Belbin roles, the students complete a questionnaire designed to ascertain the specific roles of the respondents. If there is a positive correlation between participatory levels and the Belbin roles, the roles could be taken into consideration when creating student teams. We used data collected in 2012 and 2013. We recognise that only two years' worth of data could be insufficient to establish any correlation, but it could indicate trends. These could be expanded upon as additional data is collected each year. A comparison between the presence of social loafers as well as the distribution of roles in teams was drawn.

This is based on earlier research where the presence of social loafers in a team was related to the presence of Diligent Isolates [28].

2. RESEARCH SCENARIO

This research was conducted during two consecutive presentations of a Software Engineering (SE) module offered at the University of Pretoria. This module is presented in the final year of a three-year Computer Science degree. One of the aims of the module is to consolidate the learning content of previous modules in order to design and implement a medium-sized software system. The module consists of two parts. During both parts the students undergo the complete SE life cycle. In the first part, namely the mini project, the simplicity of the waterfall model makes it eminently suitable. The mini project is completed during the first six weeks of the module. In the second part students are encouraged to experiment with a variety of agile methodologies. Our data was gathered only during the mini project.

2.1 Mini project

During the mini project the students complete the planning, design, documentation and implementation of a SE project. The students are given well defined assignments to complete during four short rounds. All the teams work on the same project. A prominent feature of the mini project is the introduction of difficulties and confusion in the learning experience. These complications are achieved by maximising risks and challenges. We expose the students to as many situations for experiential learning as possible. In each situation we set challenges which require the acquisition of SE knowledge and skills while having to deal with difficulties associated with working in teams that are likely to be dysfunctional. To maximise the actual learning that results from the opportunities created this way, we provide support. Apart from expecting the students to participate in structured reflection on their newly acquired skills, we inform them about the possible difficulties they may experience during their forthcoming rounds and give them guidelines on how to deal with expected difficult situations. We also encourage the students to seek help when needed. The different challenges introduced in the first part are summarised in Table 1.

2.2 Team creation

During the mini project the students are required to work in lecturer assigned teams. At the beginning of each round the students are assigned to new teams of 7 to 9 members. The allocation strategies differed from round to round. In some cases they were allocated randomly whereas in others certain criteria or a combination thereof were taken into account. These included Belbin roles (See Section 3, and participatory levels (See Section 5). In some cases the criteria were applied to form ideal teams whereas in other cases teams were deliberately assembled to be contrary to the ideal postulated by a theory.

Table 1: Challenges posed to the teams

Aspect	Challenge
SE	Unknown software engineering process Changing and unclear requirements Strict documentation requirements
Technical	Large project scope New technologies Intricate integration requirements
Teamwork	Large teams Team instability Team compositions that are not ideal

Table 2 shows the number of teams that were formed. The analysis reported in this paper relates to the composition of these teams as well as the behaviour of the students in these teams.

Table 2: Number of teams

Round Year	1	2	3	4	Total
2012	9	10	10	10	39
2013	9	8	8	9	34

When analysing the teams, cases where there were too few members in the team who provided the information used in the analysis, the teams were removed from the data set. We ended up analysing 69 teams; 36 teams of 2012 and 33 teams of 2013.

3. BELBIN TEAM ROLE THEORY

The personality of team members is recognised as an important factor contributing to how SE teams function [12, 20, 32]. Many general personality theories have been investigated in connection with team role assignment; for example the Keirsey Temperament Sorter [33], 16 Personality factor [1], Meyers-Briggs Temperament Indicator [16], The Five-Factor Model [37]. We think that Belbin's theory that focuses on personal behaviour in a teamwork situation may be more applicable. Alban [2] reports that team conflicts were reduced where Belbin's model was applied in team formation.

The foundation of Belbin's theory was laid in the late 1960s and is based on research with over 200 teams [6, 9, 7]. Table 3 is a summary of the eight Belbin team roles. According to Belbin's team role theory, teams in which a wide range of team roles are represented perform better than teams in which there is an imbalance of roles [30]. Ferreira and Langerman [19] observe that the Belbin roles of successful developers and business analysts support the theory. The psychometric validity of the constructs in Belbin's theory as well as instruments to measure them was heavily criticised [13]. The issues have since been addressed [4, 39, 40] but it remains controversial. Recently Batenburg et al. [5] found no relationship between team role diversity and team performance.

4. BELBIN ROLE DATA COLLECTION

Every year our students complete the Belbin self-perception inventory [8] early in the module. This is presented as a paper based questionnaire. It consists of sections in which the students have to rank and rate a number of statements to indicate how applicable the statements are to themselves [10].

After completing Belbin's test, scores are calculated for each of the eight roles. Ideally a primary and a secondary role should be assigned to a person. These should be the roles respectively with highest and the second highest scores. In our analysis we assigned roles to each student according to Belbin's recommendations, but deviated when these roles could not be determined this way. If the highest score is not unique, all roles having the same score are assigned. This way some students were assigned more than two roles. In cases where there is one role with the highest score, but the second highest score is not unique, we did not assign a secondary role.

The students are aware of these scores and the roles that were identified. They were lectured on the characteristics of the roles and advised on how they could focus on their strengths and make

Table 3: A summary of the eight Belbin team roles [6]

Type Type	**Typical features**	**Positive qualities**	**Allowable weaknesses**
Coordinator **CO**	Calm, self-confident, controlled	A capacity for treating and welcoming all potential contributors on their merits and without prejudice	A strong sense of objectives. An average intellect or creative ability
Shaper **SH**	Highly strung, outgoing, dynamic	Drive and readiness to challenge inertia, ineffectiveness, complacency or self-deception	Proneness to provocation, irritation and impatience
Plant **PL**	Creative, imaginative, unorthodox.	Can solve difficult problems with original and creative ideas	Can be poor communicator and may ignore the details
Monitor-Evaluator **ME**	Sober, unemotional, prudent	Judgement, discretion, stubbornness	Lacks inspiration or the ability to motivate others
Implementer **IM**	Conservative, dutiful, predictable	Organising ability, practical common sense, hard-working, self-disciplined	Lack of flexibility, unresponsiveness to unproven ideas
Resource Investigator **RI**	Extroverted, enthusiastic, curious, communicative	A capacity for contacting people and exploring novelty	An ability to respond to challenge. Liable to lose interest once the initial fascination has passed
Team Worker **TW**	Socially oriented, rather mild, sensitive	An ability to respond to people and situations and to promote team spirit	Indecisiveness at moments of crisis
Completer-Finisher **CF**	Painstaking, orderly, conscientious, anxious	A capacity to follow through. Perfectionism	A tendency to worry about small things. A reluctance to "let go"

up for weaknesses of other members in their teams throughout the mini project.

Figure 1 shows the distribution of number of roles assigned to the students used in our analysis.

For each team the number of occurrences of each of the roles was recorded. This could be established retrospectively regardless of the strategy used when forming the team. Thereafter the number of different roles occurring in each team was counted, regardless of the number of students with that role. In our calculation we did not differentiate between primary and secondary roles. Figure 2 shows the distribution of number of roles counted in the teams used in our analysis.

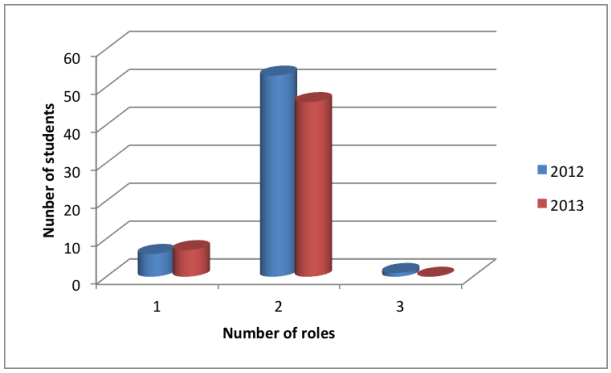

Figure 1: Number of students with number of roles

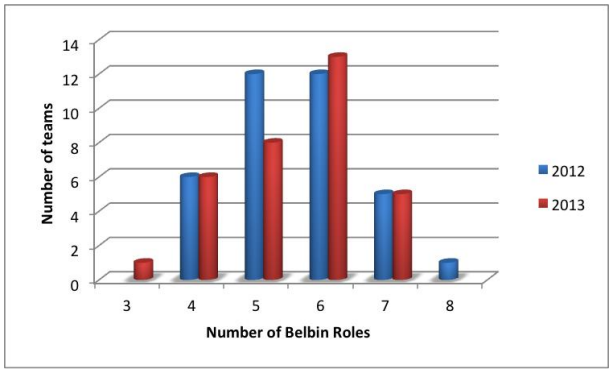

Figure 2: Number of teams with number of roles

5. PARTICIPATORY LEVEL THEORY

In order to test Belbin's theory we needed a measure of team effectiveness. Rather than defining ways to determine team effectiveness or success, we only analyse the participatory levels of the team members, irrespective of the other factors.

In our experience, when students are expected to work in teams, the levels at which they participate are often unequal. In this section, we specify some of the prominent attributes of the levels of participation previously observed by Pieterse et al. [29]. We use these specifications to analyse the levels of participation of the students. We acknowledge that the level of participation of one individual depends on many factors and may change from one situation to another. It is also important to note that these levels are not discrete. The level of participation of an individual lies on a continuum between social loafing on the one extreme and diligent isolation on the other.

5.1 Social Loafer

The term social loafer refers to an individual whose contribution is perceived to be inferior to those of others in a team. The phenomenon that participants working in groups exert less effort than participants working individually was discovered by Ringelmann [21]. Since the term social loafing was coined by Latane et al. [24], it has been studied extensively [34]. The findings of Start et al. [36] confirm that social loafing is not only situational, but is also in a complex manner related to a person's psychology. The original meaning of the term implies that all team members will equally reduce effort when working together. In educational circles, however, the term is increasingly used to refer to individuals in a team who slack more than others [22].

5.2 Compliant Worker

We use the term compliant worker to refer to a team member that usually only does what is expected of him or her. Such an individual is relatively unquestioning and likely to accept the decisions of others without reflection. This behaviour has been identified as a coping mechanism to eliminate or reduce stressors related to high workloads [26]. It is also a commonly used strategy that team members may employ to avoid conflict in a team. Compliant workers will not disappoint the team when they are expected to complete specific tasks. In a situation where there is a lack of leadership or no specific expectations, these individuals may end up being social loafers.

5.3 Insightful Shaper

We call a member who takes responsibility to ensure that the required work is completed an insightful shaper. Such an individual is called insightful because she has usually reached higher levels of emotional intelligence and is able to awaken the innate creativity of the members of the team [42]. This participatory level is also named after the shaper team role as identified by Belbin [8]. The insightful shaper is someone who provides the necessary drive to ensure that the team stays focused and retains momentum. Unlike a diligent isolate, who is usually unwilling to delegate some of the work, an insightful shaper succeeds in motivating and allowing the other team members to participate. Bukusi [14] refers to someone who kindles the ability of the members to work collaboratively to see the team through to success as a smart leader.

5.4 Diligent Isolate

We coined the term diligent isolate to refer to an individualistic member who relies only on herself to complete the set tasks. We observed that some individuals willingly increase their effort when working in teams. They tend to complete their own tasks exceptionally well, and also endeavour to redo or improve the work of other members. This phenomenon is the opposite of social loafing. Williams and Karau [41] propose a social compensation hypothesis which states that people will work harder collectively than individually when they expect their coworkers to perform poorly on a meaningful task. This finding, as in the case of social loafing, suggests that all members of a team are inclined to work harder. We, however, noticed that an individual may compensate more than others. Smarusky et al. [35] call them poor leaders, and Dixon et al. [17] refer to them as lone wolves. A diligent isolate dislikes team work and often sees others as ineffective and incapable [18]. Such behaviour may discourage the participation of other members [27].

Liden et al. [25] hypothesise mistakenly that when individuals perceive a co-worker to be loafing, that perception would encourage their propensity to loaf. Surprisingly, they observed the opposite, namely that members actually increase their effort. Kerr [23] has found that if a co-worker constantly exerts herself on a project, partners are more likely to loaf.

6. PARTICIPATORY DATA COLLECTION

We collected and analysed the data from responses provided by the students during regular peer reviews. At the end of each round the students were expected to complete a peer review in which they reflect on how they perceive themselves and how their peers perceive them.

The main purpose of each peer review was to provide a structured opportunity to reflect on their teamwork experiences in the round. Rafferty [31] emphasises the need for reflection at the conclusion of a group work experience. Through peer reviews, students get feedback from their peers. Anson and Goodman emphasise the importance of feedback because without it, students will not be able to learn to improve their behaviour [3].

The questions that the students had to answer guided them to reflect both on their own contributions and the contributions of the other members. These questions were exactly the same for all peer assessment opportunities and are discussed in detail by Pieterse et al. [29].

The responses to the peer reviews provided rich data which we analysed to establish the levels at which the students participated. We discuss how we determined participatory levels based on self-reporting in Section 6.1. In Section 6.2 we discuss how the levels of participation of the members were established based on peer-reporting. These were combined as discussed in Section 6.3.

6.1 Classification based on self reporting

In the peer review students were required to write a paragraph describing their contribution to the task of that particular round. The participatory level of each student in each round was determined by means of interpretive evaluation of this paragraph.

We independently read each of the paragraphs. Based on this we categorised each student in one of the specified levels. After the individual analysis was completed, the two sets of results were compared. In the cases where there were differences, we reconsidered the classification to reach consensus. On average 32,4% of classifications had to be reconsidered.

In many cases it was easy to reach consensus. For example the following comment was classified as social loafer by one rater while the other identified it as compliant worker.

> *Because the SMS protocol I implemented did not work as expected and it was the only 'wow factor' we had for the system*

The classification as social loafer was done assuming that if the implementation did not work, the person did not try hard enough. When considering the difficulty of the task it is possible that this implementation was not totally broken, but merely somewhat less than perfect. Because the student mentions that it was the only 'wow factor', it was important for them and not having a perfect solution was disappointing. This comment can therefore be interpreted to reveal that the person probably worked very hard but feels bad about her failure to produce a perfect solution. The consensus classification is compliant worker.

In some cases the classification remained challenging. For example the one rater classified the following comment as insightful shaper while the other rater was torn between diligent isolate and compliant worker:

I worked hard on crafting solutions to our most pressing problems while working the tasks given to me by our team leader. Specifically, designing the rule system that one of the other members used in his decoder; solving performance issues we were having with our application; writing the file manager (which is surprisingly difficult in javascript and phonegap) implementing a lot of the required functionality for our project.

The key phrase working the tasks given to me is typical of a compliant worker and yet it seems that this person feels that she implemented most of the system, including particularly difficult sections. She was attending to the pressing problems that may have been allocated to other team members. This is typical diligent isolate behaviour. Usually diligent isolates mention many specific things they have done. Attending to problems, however, need not be interpreted as actually doing them as a diligent isolate would do. It may as well be interpreted that the person is helpful and gave guidance and motivation leading to higher levels of collaboration, which is a characteristic of an insightful shaper. The consensus classification is insightful shaper.

6.2 Classification based on peer reporting

We analysed the data as a pair and took an holistic approach. We analysed one team at a time. For each team per round, the team members were classified into the four levels of participation. Various observations were made about the participatory levels of the members by analysing the data from different perspectives.

One perspective was based on the ranking of members in the team provided by each student for her team. The ranking was quantified. The two top members were assigned a value of 3, the two bottom members were assigned a value of 0, and the other members were assigned a value of 1. Table 4 shows an example of the data representing the ranking made by the members of a team rows represent the member doing the ranking and columns the member being ranked. This ranking was used as a guide to identify possible leaders (insightful shapers), and slackers (social loafers). If the majority of the members ranked a specific member low, it is likely that she was a social loafer. In this example Member 4 is a possible social loafer. Everybody except herself and Member 1 ranked her low. If the majority of members ranked a person high, it is likely that she was an insightful shaper. In this example Members 1 and 3 are possible insightful shapers.

Two other perspectives were based on the hours and the quality evaluation the students reported for themselves and their peers. Tables 5 and 6 is an example of this data provided by the same team. Here Member 4 did not estimate the hours she or her peers had worked.

Table 4: Data showing how members of a team ranked each other

Member	1	2	3	4	5	6	7
Member 1	3	1	3	1	0	0	1
Member 2	3	1	3	0	0	1	1
Member 3	3	0	3	0	1	1	1
Member 4	3	0	3	1	0	1	1
Member 5	3	1	3	0	1	0	1
Member 6	3	0	3	0	1	1	1
Member 7	3	0	3	0	1	0	1

Table 5: Data showing how members of a team estimated the hours they worked

	Hours						
Member	1	2	3	4	5	6	7
Member 1	10	5	5	4	4	4	5
Member 2	20	10	15	8	10	8	12
Member 3	10	6	8	5	6	7	9
Member 4							
Member 5	96	60	90	20	75	60	75
Member 6	18	5	15	5	8	8	15
Member 7	40	15	37	10	25	15	35

Table 6: Data showing how members of a team rated the quality of each other's work

	Quality						
Member	1	2	3	4	5	6	7
Member 1	9	8	8	7	7	7	7
Member 2	10	8	9	7	8	7	9
Member 3	10	7	9	7	8	8	10
Member 4	8	7	8	7	7	7	8
Member 5	8	6	8	4	6	5	6
Member 6	8	4	7	3	5	5	7
Member 7	10	9	10	9	9	9	9

This data was used as a guide to determine how each member perceived how the others worked in relation to herself. Cases exist where students reported that everybody worked exactly the same number of hours and all delivered work of top quality. This type of information does not reveal any team dynamics and is likely to be idealistic. Many students had a more realistic estimate of the time they worked and the quality of their deliverables. If a team member reported that she worked significantly more hours than the rest of the team members, such a student is likely to be a diligent isolate, especially if the other team members concurred. According to this reasoning, Member 1 of the example was likely a diligent isolate. Where a team member reported that she worked more or less the same hours as the others, while the others reported that she worked harder or delivered work of a higher standard than the rest, the likelihood of this person being an insightful shaper is greater. If most team members indicated that an individual worked only a few hours, it is likely that she had slacked. Member 4 of the example was probably a social loafer. Although some members did not indicate that she had worked significantly less than all other members, in everybody's view nobody worked fewer hours than she did. Similar observations can be made when focusing only on how the members rated the quality of the work delivered by themselves and their peers.

Usually observations from the different perspectives support each other, but sometimes they are contradictory. Here we took observations from all perspectives into account when deciding holistically about the team dynamics and the participatory levels of the members. If there were multiple indications that a member had participated at a certain level, she was classified accordingly. For example, observations from all perspectives indicated that Member 1 was a diligent isolate; she was therefore classified as such. In this example the perspective of quality did not indicate that Member 4 could be a social loafer as strongly as the perspective of time spent. The fact that she did not answer all the questions in the peer review, is an additional indication that she may be a social loafer. We classified her as a social loafer based on taking all the indications into account. If a person did not stand

out in any way she was classified as a compliant worker. In cases where some members of a team did not complete the peer review, we classified those students based on what the other members reported about them. In cases where too few students in a given team provided information, the members of such teams were not classified.

6.3 Merging the classifications

We determined the correlations between the classifications based on self reporting and on peer reporting across all rounds for data collected and analysed over 2011 to

2013. The classification data was captured as ordinal variables with higher values corresponding to a higher inclination towards working. The distribution of the data was assessed for normality before calculating the Pearson's correlation coefficients between the pairs of data for the different rounds. Due to slight deviations from normality observed in some cases and the categorical nature of the nominal variables, the non-parametric Spearman's rho correlation was calculated to corroborate the parametric correlation results. Table 7 shows the Pearson's correlation and Table 8 the Spearman's rho correlation between the two sets of data. All correlation coefficients are significant and range from small (.3) to large (.8), indicating acceptable correspondence between the role classifications based on self reporting and peer reporting data. The two sets of data are similar enough to use either one for further analysis.

The level of participation determined by using the peer reporting is more comprehensive because we could classify students who did not respond, based on what the other members of their teams reported about them. Rather than just using the more comprehensive data, we decided to use the union of the two sets. Where there were discrepancies, we retained the classification based on self assessment because we have greater confidence in its accuracy. In our experience, students are more likely to be honest about their own participation than their peers'. This may be ascribed to peer pressure and a desire to support team mates.

Table 7: Pearson's correlation between the classifications

	2011	2012	2013	Overall
Round 1	.670**	.369**	.298*	.468**
Round 2	.354**	.418**	.750**	.531**
Round 3	.459**	.628**	.781**	.597**
Round 4	.356**	.435**	.642**	.491**
Round 5	.421**	.408**	.413**	.402**
** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).				

Table 8: Spearman's rho correlation between the classifications

	2011	2012	2013	Overall
Round 1	.622**	.371**	.362**	.468**
Round 2	.367**	.433**	.724**	.523**
Round 3	.478**	.589**	.704**	.574**
Round 4	.332**	.481**	.670**	..503**
Round 5	.455**	.432**	.391**	.420**
** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).				

6.4 Measuring teamness

Bukusi [14] describes teamness as follows:

> *The concept of teamness is not a typographic error. It is an intangible feature of a team's performance and ability to succeed. Because corporate teams are mainly assembled for their technical skill and prowess this aspect of teamwork is often downplayed at the beginning, but inevitably shows up in the field when pressure and problems build up.*

If teamness could be quantified, teams with high teamness are more likely to succeed. For this study we assume that the number of identified social loafers in a team is an indication of team malfunction. Teams in which social loafers could be identified are deemed less effective than teams without social loafers. The number of social loafers could be a measure of the opposite of teamness.

For each team the number of identified social loafers were counted. Figure 3 shows the distribution of number of social loafers counted in the teams used in our analysis.

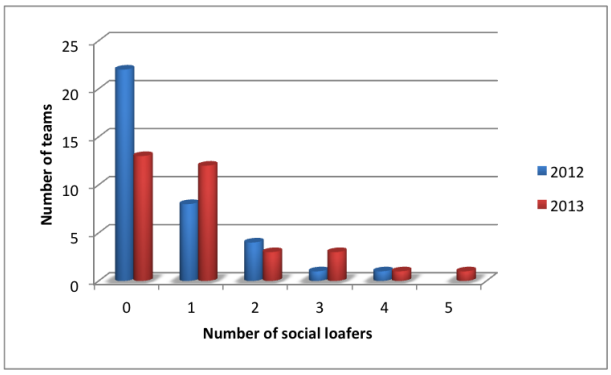

Figure 3: Number of teams with number of social loafers

There were 22 teams with no social loafers in 2012, whereas in 2013 there were only 13. This is an indication that the teamness in 2012 was better than in 2013. It is not common to have more than one social loafer in a team. There is only one team in 2013 that had five social loafers. In this case two of the seven members completed the task on their own and did not bother to keep the rest of the team informed or to incorporate them.

7. VALIDITY OF BELBIN'S THEORY IN OUR CONTEXT

We investigated whether the number of Belbin roles in a team has an impact on the number of social loafers in a team. Figure 4 shows the average number of social loafers in teams against the number of Belbin roles in the teams. In 2012 the number of social loafers peaked at seven roles and dropped to zero at eight roles while in 2013 the number of social loafers was zero at three roles, peaked at six roles and dropped significantly at seven roles.

Figure 5 shows the average number of Belbin roles in teams against the number of social loafers in the teams. In 2012 there is an insignificant trend towards more social loafers as the number of Belbin roles increase. This trend is contrary to Belbin's theory that more roles lead to better functioning teams. In 2013 there is no discernible trend.

Based on these observations, it seems that there is no correlation between the number of social loafers and the number of Belbin roles per team in terms of any of these perspectives. The lack of correlation is more evident in Figure 4. With this data and our measure of team effectiveness, we are unable to confirm or refute Belbin's theory.

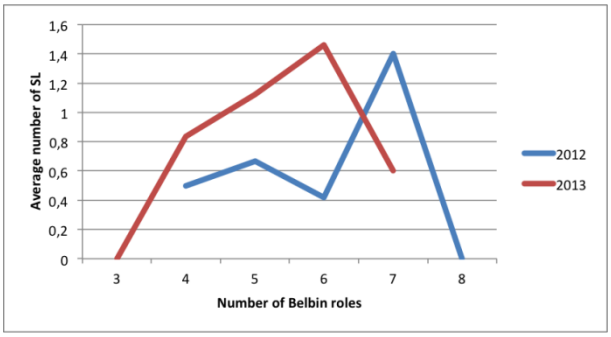

Figure 4: Average number of social loafers per number of Belbin roles

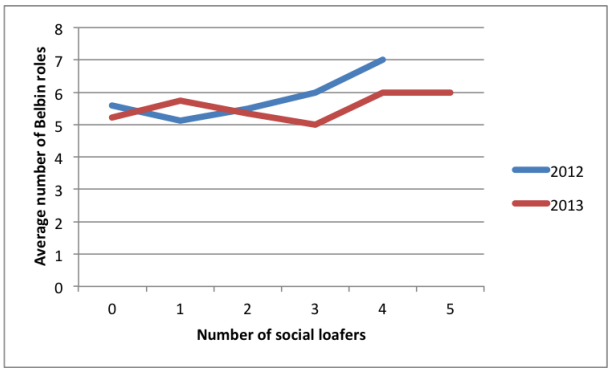

Figure 5: Average number of Belbin roles per number of social loafers

There are a number of factors that could have influenced the validity of our results. These include

- We analysed limited data. Only a small number of short-lived teams over only two years were investigated. The results may become more conclusive once the amount of data is increased.
- The team role definitions of the students in the analysed teams may be inaccurate. Belbin [11] acknowledge that those who have been in the work environment for a longer period of time are likely to have more defined or polarised Team Role preferences while inexperienced individuals may be less sure of their contribution and their Team Roles do not seem so well-defined. The sample that Belbin used in his research consisted of Masters' students, who are likely to have had more exposure to teamwork and who are significantly older than our third year students.
- Many of our students have difficulty with English and it is possible that some of the options in the Belbin test were not clear enough for them to answer the questions accurately.
- The participatory levels of the students in the analysed teams are vulnerable to misinterpretations. Despite our rigorous analysis, the classification is subjective and anomalies may occur.

8. RESEARCH OPPORTUNITIES

We are interested in conducting research related to the following topics for which we are seeking research collaboration in other institutions

- The development of strategies to use identified participatory levels of students for early identification of teams at risk in the main project in order to be able to provide better guidance.
- Gathering of more data over a wider range of scenarios in order to produce more conclusive results.
- The creation of an instrument similar to the Belbin test, but having fewer role options, and which is geared to the lack of experience of our undergraduates. Care should be taken to ensure that the language used in the instrument is more accessible.

9. CONCLUSION

We described the participatory levels of students in teams based on several findings over a wide range of research areas. These levels are easy to understand and apply when the behaviour of students in teams are observed.

We described our method of data gathering and analysis to determine the participatory levels of students. It includes many aspects that are subjective in nature, ranging from the student's views about themselves and their peers to the opinion of the researchers who analysed the data. Despite this, the resulting data seems credible.

We illustrated how the participatory levels of members in their teams can be applied when we investigated the validity of Belbin's team role theory in our context. We believe that these participatory levels can be applied in research covering a large scope of topics related to team dynamics.

We failed to establish any correlation between the number of social loafers in a team and the number of Belbin roles represented by the members of a team. This failure is likely related to inaccurate information about the Belbin roles of the team members rather than being a consequence of misinterpretation of the levels of participation observed in the teams. Closer analysis is needed. It may be worthwhile to investigate whether the occurrence of certain combinations of Belbin roles is predictive of the presence of social loafers in a team.

Despite the inconclusive results we have laid some groundwork for research aimed at improving the teamwork experience of our students and refine our teaching of teamwork skills. We have also identified several research opportunities and seek research collaboration to enhance the credibility of our work.

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Assessment for Learning: Using Formative Assessment to Scaffold Students' Fragile Knowledge

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ABSTRACT

While the importance of equipping students with computer skills in their first year at university is widely accepted, the practicalities of assisting struggling students call for an exploration of different approaches to help students learn these critical skills. This paper, based on a study located in a small research-intensive university in South Africa, seeks to illustrate that the use of multiple formative assessment tasks has the potential to encourage a better understanding of the assessment criteria and help students succeed.

Three formative assessment tasks were implemented in a Computer Skills course to counter the challenges faced by students in a Microsoft Excel module. These challenges related to their fragile knowledge of spreadsheet functions, i.e., failing to remember, understand or effectively apply the functions they had learned to solve different spreadsheet tasks. Formative feedback principles were used to scaffold this fragile knowledge, empower the students to understand the assessment criteria, and hence close the feedback loop. As a result of these formative assessment tasks, students' average assessment marks for the module assignments increased and the students supported the use of these assessment methods in their course evaluations.

Categories and Subject Descriptors

K.3.1 [**Computing Milieux**]: Computer Uses in Education – *computer-assisted instruction (CAI), collaborative learning*

General Terms

Human Factors

Keywords

fragile knowledge, formative assessment, Microsoft Excel, scaffold, assessment criteria, feedback loop.

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1. INTRODUCTION

The first year Computer Science curriculum is considered difficult by most students, with high failure and dropout rates reported in universities around the world [9, 10, 23]. Different reasons for the large number of dropouts and failures during this first year have been observed. [11] posit that some Computer Science lecturers still use outdated methods by teaching "computer science in much the same way [they] learned it". These lecturers may struggle with accommodating a diverse student body and ignore the fact that students' interactions with computers have changed significantly over the last few decades. They are often viewed as the guru, "the professor… who ha[s] the knowledge and impart[s] it to students from an ivory tower of authority" [17].

Another possible reason for the high failure and dropout rates is the difficulty in developing computational thinking – a complex skillset needed by Computer Science students in order to learn to problem-solve and programme effectively [28]. Computational thinking includes problem analysis and abstraction, mental models, as well as syntax and semantics of the computer application or programming language [23, 28]. In their first year of Computer Science, students are introduced to some of these skills for the first time, and may struggle with this knowledge by failing to "remember, understand or use actively much of what they have supposedly learned" – a learning challenge better known as 'fragile knowledge' [21].

Other possible reasons that have been put forward to account for such failure include the students' attitude about their ability to succeed [3], students' programming aptitude [9], and the motivation level and learning approach the students use [23, 25]. Although both students and lecturers have been identified as contributing to the low success rate in first year Computer Science, it is the lecturer who bears the duty to provide an engaging and enabling online and classroom environment in order to motivate a "deep approach to learning" [12]. The ability of the lecturer to scaffold students' fragile knowledge and provide models and links to what the students already know, may improve students' attitude towards the curriculum and help them better understand and apply what they have learned.

In this paper, I report on an exploratory case study where formative assessment tasks were used to scaffold students' fragile knowledge in a Computer Skills introductory course. Class

discussions and feedback from peers in the online space were also used to help the students understand the assessment criteria. The next section discusses the context within which this learning intervention took place.

2. CONTEXT

At the time of this intervention, the Computer Skills course was offered over one year to Extended Studies (ES) students – these are students who are given extra support in their first year at university. In this course I introduced the students to a range of theoretical concepts and computer applications, including Internet and email, Word Processing, Spreadsheets, Databases, Presentations, HTML5, Information Systems and introductory programming with Python or C#.

In order to engage students with different levels of experience with computers, cater for a variety of learning styles, prompt students to apply their knowledge and skills in new situations and develop life-long learning skills, I used a blended learning approach [27]. The blended approach included two weekly 90-minute face-to-face sessions with the lecturer, plus one weekly 90-minute tutorial session with the tutors, with extensive use of the University's Learning Management System (LMS) for in and out of class teaching and learning activities. The aim of the blended approach was to seamlessly integrate the face-to-face sessions with technological affordances in order to provide the students with a "holistic [and] superior learning experience" that addressed teaching and learning challenges [7].

Although most of the formative assessment activities reported on in this paper took place during the face-to-face sessions, I used the LMS in the following ways: 1) to give students access to the resources they needed in order to complete each assigned task; 2) to allow students to submit their completed work by uploading it; 3) to give students access to completed tasks that needed to be peer assessed; 4) for students to submit feedback to their peers; 5) to complete the minute paper which was structured as a short online questionnaire; and 6) to continue the class discussions in the online forum.

I selected the Microsoft Excel module for this exploratory case study for two reasons. Firstly, spreadsheets provide an introduction to computational thinking skills, which are often difficult for first year Computing students to grasp and apply. The formative assessment tasks were designed to assist students to make explicit their problem-solving processes and articulate their rationale for selecting a particular course of action. Secondly, I noted over the first few weeks of the Microsoft Excel module that most of the students in this class were struggling with spreadsheet functions in one of four ways: a) students were unable to figure out what a problem question required them to do; b) students found it difficult to select the correct spreadsheet function to use unless prompted by the teacher or a tutor; c) students applied the wrong function, even when it was syntactically correct; and d) students applied the correct function to a problem, but used the wrong variables and syntax. These four types of challenges relate to the four categories of fragile knowledge, discussed below, with which computer novices generally struggle.

3. COMPUTER NOVICES AND FRAGILE KNOWLEDGE

Computer novices, and the process by which they acquire computer skills, have been the focus of research studies for decades [14, 20, 23, 29]. Novices seem to struggle with a number of issues, including: building adequate mental models, surface knowledge and superficial organisation of that knowledge, weak problem-solving approaches [23, 29] and disorientation or lack of comprehension when they attempt problem specifications [23]. This is concisely expressed by [20], who posit that most students exhibit fragile knowledge of the required skills, where a student "sort of knows, has some fragments, can make some moves, has a notion, without being able to marshal enough knowledge with sufficient precision to carry a problem through to a clean solution" [20]. The students' knowledge needs to be scaffolded in order for the student to remember, demonstrate understanding and actively act upon the knowledge.

The term 'knowledge' has a varied array of classifications and levels; hence the need to clarify what I mean by 'knowledge' in this paper. In the Microsoft Excel module, students are required to learn various procedures for completing specific tasks, and applying this skill to new situations. This is termed procedural knowledge, or "know how" knowledge, where the goal is simply to "know how to do it" [16]. This procedural knowledge entails defining the problem, selecting and implementing the best solution, and evaluating or justifying this solution [16]. It involves acquiring a set of skills and using these skills effectively to perform a specified task to solve a problem. Therefore, the fragile knowledge that students exhibited in the Microsoft Excel module discussed in this paper refers to the lack of, or failure to apply, the procedural knowledge related specifically to spreadsheet functions.

Fragile knowledge can be classified as missing knowledge, inert knowledge, misplaced knowledge or conglomerated knowledge [20]. Students in the Microsoft Excel module displayed each of these different classifications of fragile knowledge as outlined in the examples below. Missing knowledge is a situation where there are gaps in the students' learning. The student may have failed to learn or may have completely forgotten what was learned. In the spreadsheet module used in this study, missing knowledge indicates that the student does not understand the assessment criteria, and therefore fails to figure out what is required by the particular assessment task. Inert knowledge refers to a situation where a student fails to use the knowledge they have acquired to complete a task, unless prompted by the teacher or a peer. The student appears to have acquired the procedural knowledge, but does not use it in a relevant problem-solving situation. With regards to the spreadsheet modules, students with inert knowledge were unsure of the spreadsheet function to use to meet the assessment criteria until prompted by the teacher or a knowledgeable peer. With misplaced knowledge, a student

manages to structure the solution correctly, but applies it to the wrong context. For example, a student may wrongly apply a spreadsheet function, even if the function itself is syntactically correct. Conglomerated knowledge refers to a situation where a student combines elements of knowledge that are not related to each other. This application "loosely expresses a desired intention" [26], but ignores the important elements of syntax and semantics. In this case, the student is presumed to understand the assessment criteria because the correct function is selected. However, the student uses incorrect variables or structure for the spreadsheet function.

4. ASSESSMENT FOR LEARNING

In order to effectively use assessment, [15] assert that the teacher needs to be clear on the goal of the assessment: judging students' performance or aiding the learning process. [13] distinguish the two as "assessment of learning" (summative assessment) and "assessment for learning" (formative assessment). Formative assessment places less pressure on students to perform for marks, and they can concentrate on responding to feedback from the teacher or their peers. This paper reports on the implementation and evaluation of formative assessment tasks that seek to aid the learning process, rather than judge student performance.

In order for the formative assessment to benefit both the teacher and the student, there has to be timely and useful feedback. The teacher uses feedback to diagnose and remediate students' work, while students use it to reinforce their strengths and improve on their weaknesses [24]. Hence, formative feedback can "provide information to teachers that can be used to help shape…teaching" [19]. This further implies that comments and marks given back to the students can only be termed feedback if they are used by students to improve performance [19]. This highlights a perennial problem in Higher Education: how to ensure that feedback to students is clear and how to motivate the students to close the feedback loop.

Three formative feedback principles emerge from this, which [24] articulates as:

1. The student should understand the assessment criteria in roughly the same way that the teacher does. In order for students to become conversant with the criteria, they should already have experience working with it [5] through peer or self-assessment [19], and dialogue between the teacher and the students.
2. There is a clear comparison between the student's current performance and the required standard. Good feedback "provides opportunities to close the gap between current and desired performance" [19]. To assist students in 'closing the gap', the teacher could discuss action points with the students to help them identify the next step in using the feedback to better comply with the criteria.
3. The student should be able to engage in action that will essentially close the gap between the current performance and the desired standard. Therefore, feedback should "be conducted at the level of individual learners" [13], and should motivate the students to improve their performance [19]. If the feedback is passed on to a student "who lacks the knowledge or power to change the outcome, or is too deeply coded… to lead to appropriate action" [24], then the student is powerless to use the feedback to close the knowledge gap and complete the feedback loop.

Finally, feedback from students (or course evaluations) can inform teaching. This can be done, among other methods, through minute papers, questionnaires to students, assessment tasks, student observations as they work and encouraging students to tell the teacher where they are having difficulties.

When using formative assessment, [5] caution "that all forms of assessment discriminate in some way against some groups of learners". A lecturer who decides to use only one assessment method (e.g. essays) will cripple some students' learning as they may not reach their full potential in the course. A limited number of competencies will be tested with this one method, thereby prejudicing students who are weak in that area. Testing a range of skills through multiple methods also improves the validity and fairness of the assessment task as well as bringing variety to the students' learning and enriching the assessment function.

In order to assist the students to better understand the assessment criteria, as well as maintain validity with the multiple assessment tasks, criterion-referenced assessment (CRA) was used in this exploratory case study. CRA is where a student's performance is compared to "pre-specified criteria or standards" [15]. If criteria have been specified for an assessment task, these need to be clearly communicated to the students because they are only able to achieve the goal specified in the criteria if they understand it, own it and can assess how well they have progressed towards the specified goal [19]. The criteria in the assessment tasks discussed in this paper are articulated to the students in various ways. In fact, some of the assessment tasks have been designed to aid students to internalise the assessment criteria.

5. IMPLEMENTATION OF ASSESSMENT TASKS

My goal in using the formative assessment tasks and related feedback was aligned to the three formative feedback principles discussed above, namely: 1) to improve the students' understanding of the assessment criteria; 2) to clarify for the students where there was a gap between their knowledge and the required assessment standard; and 3) to empower the students to close this gap. There were three formative assessment tasks, and the marks for these tasks were not recorded in order to remove the pressure of performing for marks.

5.1 First Task: Function Matrix

The first of the three tasks in the multi-assessment method involved the use of what [1] term the memory matrix. I renamed it the Function Matrix (for Microsoft Excel functions) because the purpose of the matrix was changed, and only its original structure was maintained. The Function Matrix consists of a table with rows and columns used to assess students' understanding of concepts. Because of its layout, it provided me with a visual representation of patterns in students' understanding, and a convenient way to assess the four areas students were struggling with, and a way to provide adequate feedback to them.

The students usually complete their spreadsheet exercises in Microsoft Excel, in which they get assistance from the screen tips or the Help function. The aim of the first assessment task was to move the students away from Microsoft Excel, and encourage them to think about the functions and the related variables they were selecting for each question, in order to be able to justify their choices. After setting a spreadsheet exercise similar to the ones the students had been struggling with, I provided them with two documents to assist them in completing the exercise: 1) a jpeg image of the completed worksheet, which would help them use similar cell numbers in their formulas and functions, and 2) a blank Function Matrix which contained only the headings, and which the students filled out on the LMS. Table 2 below shows three of nine completed questions on the Function Matrix.

The decision on which items each column should contain was guided by the recurrent problems exhibited by the students: unable to figure out what a particular question was asking them to calculate, selecting the wrong function, and using the wrong variables in the right function. Students were able to access the exercise problem, together with the jpeg image of the completed spreadsheet and the Function Matrix on the University's LMS. I allocated 45 minutes of class time to complete the Function Matrix, and I was available during this time to scaffold the students' fragile knowledge with leading questions and prompts.

Table 1: Function Matrix for First Assessment Task

	What are you calculating?	**Function(s) to Use**	**Full Function/Formula**
1	Tuition fees	VLOOKUP or IF statement	=VLOOKUP(C3,$B$15:$C$20,2) or =IF(C3=1,6000,IF(C3=2,5500,IF(C3=3,5300, IF(C3=4,5000,IF(C3=5,4500,4000)
4	Number of students with overload (more than 6 credits)	COUNTIF	=COUNTIF(C3:C12, ">6")
8	Average credits by non-borders	SUMIF, COUNTIF, division	=SUMIF(B3:B12, "Non-border", C3:C12) / COUNTIF(B3:B12, "Non-border")

5.2 Second Task: Presentation and Dialogue

The second of the three assessment tasks involved class presentations, where individual students presented their responses to each question. Their answers were displayed to the whole class with a projector. Each of these students had to explain the rationale behind their spreadsheet function choice. Other students were encouraged to make objections when they picked up any errors from the presenter. This method is similar to what [2] call "the fine arts approach to teaching," which shifts the burden for teaching to the student, and helps students get used to putting their knowledge on display. Students then become "accustomed to hearing one another talk about their work – in students', rather than only in professors', terms and through different ways of learning by example as well as principle" [2].

This exercise was also instrumental in scaffolding the students' inert, misplaced or conglomerated knowledge. Listening to their peers talk through their solutions prompted the students to think differently about the way they had filled out the Function Matrix. During the discussion session, the more knowledgeable students were explaining the difficult concepts very differently from the way I did, but in a way their peers could better understand. This discussion continued in the online forum.

5.3 Third Task: Peer Assessment

[22] defines peer assessment as "students… making assessment decisions on other students' work". Although I was initially sceptical about using this method, especially considering how sensitive some of the students can be when it comes to sharing their marks with peers, a number of authors gave compelling arguments about the effectiveness of peer assessment in deepening students' understanding of both the subject area and the assessment criteria [4, 15, 22]

The third and final assessment task was administered in order to encourage the students to not only read through the formative feedback I gave them, but to actively seek to understand and apply it in order to meet the assessment criteria and begin to close the feedback loop. This would also imply that they had a better understanding of the assessment criteria, and were better equipped to close the gap between their current performance and the requirements of the assessment task. The final assessment task was set in a similar format to the previous ones, and was testing all the functions covered up to that point. After the students completed it in Microsoft Excel, they peer-assessed each other's work using the assessment grid I normally used to give them feedback on their work. This online assessment grid contained complete solutions to all the functions.

During the peer assessment exercise, the problems had to be assessed on the computer screen in order to view all the formulas and formatting used. After explaining how the marks were normally allocated, I gave the students 20 minutes to assess the

task and give appropriate feedback. Most of the students gave comprehensive feedback, including pointing out where their peers had missed the mark, and what could be done to close the gap.

6. EVALUATION OF EFFECTIVENESS

In evaluating the effectiveness of the three formative exercises, I attempted to go beyond my personal reflections and analysis. [8] caution teachers against focusing on just their own personal experience of the learning process, but, instead increasing the "validity of evaluations…by gathering and analysing data from several sources".

A minute paper is a quick and effective way of collecting student feedback on their learning [1]. It usually comprises of one or two questions, with students responding to the question(s) on a piece of paper. The anonymous responses may be student reflections or evaluation of a particular concept or lesson.

I used the minute paper extensively for the duration of the Computer Skills course. Rather than writing out their responses on paper, I administered the minute paper online as a short questionnaire on the university's LMS because it made it easier to manage and store the student responses. I usually allocated three minutes to complete the minute paper in order to give students time to reflect and respond to the question(s). After the peer assessment exercise discussed in the previous section, an online minute paper was administered, with the following questions:

1. Did the peer exercise and the preceding class discussion help you to better understand the use of functions in Microsoft Excel?
2. Do you think we should use peer assessment in the future?

The structure of these questions could probably elicit a Yes or No response. But the students had used the minute paper extensively in the course, and they were familiar with the reflective response I was seeking.

In order to evaluate the effectiveness of this multi-task assessment, I also examined the students' summative assessment marks over the few weeks following this intervention. This allowed me to compare the students' overall performance before and after the intervention.

7. RESULTS AND DISCUSSION

This research entailed three assessment tasks, which were then evaluated to determine students' experiences of these tasks and shifts in their learning. 18 students out of 24 responded to the online minute paper, and their responses indicate that the majority of the students felt the class discussion and peer assessment were useful exercises in helping them better understand Microsoft Excel functions. The chart below (Figure 2) shows the number of students who responded Yes or No to the two questions in the online minute paper.

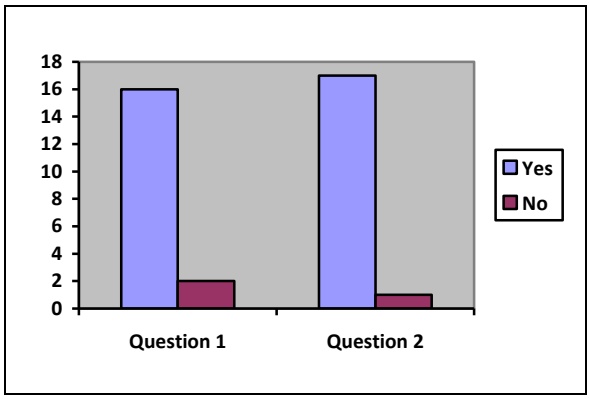

Figure 1: Student Responses to Online Minute Paper

The discussion of the results will be based on the three formative feedback principles and the importance of scaffolding and probing fragile knowledge in order to assist students in applying it to the appropriate situation.

7.1 Objective 1: To improve the students' understanding of the assessment criteria

In order to help students understand the assessment criteria in roughly the same way the teacher does, I have to initiate opportunities for them to interact with the criteria through individual work, dialogue and peer assessment. In the first individual assessment task (the Function Matrix), students had their first guided opportunity to interact with the criteria. The presentations and accompanying discussions helped the students rationalise their decisions, and think more deeply about the criteria. The final assessment task gave them the opportunity to further interact with the criteria by giving online feedback to their peers based on the assessment criteria. I was also available during each of the three assessment tasks to stimulate students' fragile knowledge through leading questions and prompts. These instances gave students the opportunity to become intimate with the assessment criteria.

Some of the responses to the online minute paper indicated that the students had a better understanding of the assessment criteria:

I could easily detect [the other student's] mistakes on the formulas and that also made me realise some of my mistakes on my assignment.

It showed me a different way of doing things and also the neatness of the work compared to mine.

7.2 Objective 2: To clarify for the students where there was a gap between their knowledge and the required standard

Once the students understood the assessment criteria, my next step was to flag the importance of reading and acting on the feedback I gave them. This feedback clarified for the students which areas they still needed to work on in order to improve and meet the requirements of the assessment criteria. A number of responses from the online minute paper indicated that the three

assessment tasks assisted the students in identifying the gap between their performance and the standard required by the assessment criteria:

It helped me a lot because I actually saw where I went wrong…

It made me understand more and realise my mistakes, which I think is good and not easy to forget.

It helped me to realise that I, myself also still need to do lot of practicing, and to understand how the formulas work.

7.3 Objective 3: To empower students to close this gap

In order for formative assessment to be effective, students have to be willing and able to close the feedback loop. This assumes the students have fulfilled the first two steps, i.e. understanding the criteria and identifying the gap. Closing the feedback loop refers to students' ability to engage in action that will essentially close the gap between the current performance and the desired standard. Feedback from the online minute paper indicated that the students felt empowered to close the gap between their current knowledge and the required standard.

…Helped me understand which formulas to use and when to use them.

Well I saw where my mistakes were at and it really gave me an insight of how to use these formulas, I think it's a great idea and should be repeated rapidly.

It helped me see my mistakes, understand what I should have done instead of what I did.

Over the next few weeks, the students' average marks for Microsoft Excel assigned tasks increased from an average of 56% to 68%. They seemed to better handle the problem areas that they had had prior to this intervention: unable to figure out what they were supposed to be calculating, selecting the wrong function, and using the wrong variables or syntax in the right function. The students were also asking better questions during their lab sessions with the tutors. They knew which function to use and when, and progressed from "I don't understand what this question is asking me to do," to syntactical questions like "why is my IF statement giving me an error?" The challenge for me as the teacher was to train the tutors to effectively scaffold the students' knowledge without taking the easy road – providing them with the solution.

7.4 Negative Feedback

Despite the positive responses to the three formative assessment tasks, two students gave negative feedback with regards to the peer assessment. They felt that it was a waste of time and they did not trust the judgement of their peers. One student cautioned the lecturer to only use peer assessment for formative, not summative purposes. Peer assessment does sometimes elicit negative feedback from students, where they either do not trust the process or they lack confidence that their peers will assess them effectively [18].

8. CONCLUSION

This paper reported on the implementation of a multi-task assessment aimed at scaffolding students' fragile knowledge of Microsoft Excel functions, and facilitating an enabling environment for the students to close the gap between their current knowledge and the assessment criteria. The students' fragile knowledge manifested itself in four ways: a) students unable to figure out what a question required them to do; b) students unable to select the correct spreadsheet function to use unless prompted; c) students applying the wrong function, even when it was syntactically correct; and d) students applying the correct function to a problem, but using the wrong variables and syntax.

I employed multiple formative assessment tasks in a Computer Skills course in order to cater for different learning styles. I designed the multi-task assessments to assist the students in closing the formative feedback loop through understanding the assessment criteria in much the same way the I as the teacher did, clarifying for them where their work missed the mark, and encouraging them to improve their weaknesses by raising them performance to meet the assessment criteria.

Based on the responses to the minute paper, most of the students appreciated the use of formative assessment tasks. They felt that the assessment tasks empowered them to respond to the formative feedback and close the feedback loop.

A limitation of this study was the small number of participants who were part of this class, and the even smaller number of respondents who filled out the online minute paper. A second limitation is that the study was located in a small department with a different structure, dynamics and course length from the main stream Computer Science curriculum in this University and in other institutions of Higher Education. Hence, there may be vastly varied factors influencing the success of a similar intervention in other Computer Science departments.

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Do Visualizations Ease Dissertation Assessment?

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ABSTRACT
South Africa is working hard to improve the education levels of all their citizens, and, as a consequence, many South African Universities have seen an impressive increase in the number of postgraduate students. On the other hand, South African Universities have not been able to employ experienced supervisors at the same rate. Given the increasing workload, examiners struggle to maintain their own high standards of consistency, accuracy and fairness. Assessing dissertations requires a serial traversal from beginning to end, sometimes repeatedly, since words are an imprecise communication tool and writing ability variable. Is there any way of making the process more efficient while retaining rigour? We cast the net wide to find a way, and, in doing so we noted the emerging use of visualization as a communication facilitator in other areas of academia and decided investigate it as a mechanism for easing the assessment process. As a first step, we need to determine the current extent of usage. Such usage is not incentivized nor is it explicitly rewarded. If we detect an impact on final grades, this will justify further investigation. We carried out a study that revealed weak correlations with the final grade, depending where the visualizations appeared and also consulted supervisors for their views. The contribution of this paper is to suggest a discourse on the deliberate deployment of visualization to ease postgraduate assessment.

Categories and Subject Descriptors
I.2.6 [Learning]: Knowledge acquisition

General Terms
Measurement, Performance, Standardization

Keywords
Visualization, postgraduate assessment

1. INTRODUCTION
Academics in South African Universities are under increasing pressure. There are a number of reasons, including the following:

1. Universities across the globe are enrolling increasing numbers of postgraduate students [16, 26]. In South Africa, in particular, the pressure on institutions and academics to deliver more postgraduates is rising [3].
2. I'Anson and Smith [17] mention the pressure that comes from millennium trends in higher education including widening access, coping with large groups of students and the increasing occurrence of plagiarism.
3. The realities of the South African society has led to the admission of student cohorts who vary in readiness for post graduate study. They also argue that it places additional pressure on supervisors to provide the necessary interventions the students need to meet the exit standards of postgraduate study [28].
4. Besides postgraduate supervision and evaluation, University lecturers also have other responsibilities like tuition, community engagement, academic citizenship, administration and carrying out their own research [25].

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More students, with the same number of academics under increasing pressure, mean more dissertations to be assessed in the same time period. For example, at the University of South Africa the number of dissertations more than doubled from 2010 to 2012 while the supervision capacity did not increase accordingly [29]

Examiners are challenged by the need to apply assessment metrics consistently under mounting workloads. Calls for less ambiguity in assessment of dissertations exacerbate the pressure on examiners [30]. Some Computer Science departments implement double marking in order to ensure fairness. However, Pathirage, Haigh, Amaratunga, Baldry and Green [23] argue that this can lead to game playing by markers, with marks converging to the average since that strategy successfully avoids the attentions of stakeholders who might question the awarded mark if it were to be extreme in either the high or low direction. In the long run these strategies could lead to students not getting the marks they deserve. Annetts, Jones and van Deursen [1] investigated the process of peer review in conjunction with developing communities of practice within research teams to maintain the high level of reliability whilst achieving the aim of reducing double marking. An in-depth discussion on assessment methods is beyond the scope of this paper but these studies are noted to support the argument that there is pressure on examiners (not all of whom are equally experienced) to deliver high quality assessments, under severe time constraints. That necessitates some kind of support mechanism to ease the assessment process while maintaining fairness. The time taken to examine a masters dissertation is more or less directly proportional to the number of

pages since the examiner has to read through the entire dissertation in order to assess it and assign a grade.

Many examiners will attest to the value of an abstract in delivering a quick overview before they embark on the detailed reading process. It helps them by giving a meta-view of the content and establishes a set of expectations in the examiner's mind. However, textual abstracts have two limitations: they, too, are processed sequentially and the limited length of abstracts, by their very nature, constrains their information payload. Moreover, an abstract delivers an overview of the research report as a whole, and does not necessarily deliver insight into the level of knowledge mastery achieved by the student in particular areas.

Are we, as examiners, missing some valuable mechanism that could make this assessment process more efficient? Is it possible that we could require students to provide something extra, or different, to ease the process, while at the same time providing a benefit for the students too? We searched for this "silver bullet", and we discovered something that seemed to have this hidden potential. Some conferences[1] have recently started requiring academics to provide video previews of their papers, and Elsevier[2] asks for graphical abstracts of accepted papers. CHI 2014 said the video previews were intended to "…*to help them (readers) discover interesting and important work* …" Elsevier states that graphical abstracts: "… *allow readers to quickly gain an understanding of the main take-home message of the paper*". Hence these more visual summaries essentially augment the papers, providing the potential reader with a snapshot that can be quickly assimilated as a unit, in parallel, far more efficiently than reading the entire paper or, apparently, the textual abstract.

Visualizations, in general, have characteristics that make them a powerful communication mechanism [6]. Most humans interpret images better than they do words: images communicate with our emotions and can thus inspire, appeal, motivate and energize since they impress, express and represent reality [4]. According to Burkhard [5] p.242) *'knowledge visualization examines the use of visual representations to improve the transfer and creation of knowledge between at least two persons'.* Such visualizations can be expected to communicate very effectively and efficiently.

The publishers we mentioned may well have identified a way to speed up and improve assessment. Their emergent practice led us to wonder whether visualizations might have a role to play in easing assessment of postgraduate dissertations too. We focused our attention on a South African University since these Universities are particularly affected the above-mentioned pressures. We carried out an investigation into how visualization had been used in postgraduate dissertations published over a ten-year period. The sample of 22 Information Systems dissertations represents 73% of the dissertations completed during that period (2002-2012).

We found that visualizations did indeed appear in these dissertations and we also found evidence that their distribution across the dissertation chapters seemed to impact the final grade. Such a finding, especially since the sample is small and the correlations were relatively weak, does not imply causality. It does suggest that we need to open up a discourse on the use of visualization in postgraduate assessment. In the next section we provide an overview of related literature on visualization in information and knowledge transfer before we present the findings of our study.

2. LITERATURE REVIEW

First, the Basics

It is important to understand the basics before proceeding to any discussion of how these can be represented. The fundamental constructs are those of data, information and knowledge. These can be described as follows [7]:

- **Data -** a representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by human beings or by automatic means.
- **Information** - the meaning that is currently assigned by human beings or computers to data by means of the conventions applied to the data.
- **Knowledge -** understanding, awareness, or familiarity acquired through education or experience. Anything that has been learned, perceived, discovered, inferred, or understood. The ability to interpret information.

Research generates data; the researcher attributes meaning to it, and thereby converts it to information. Interpretation of this information potentially delivers insights that can be termed "new knowledge" [22]. Knowledge Visualization can be described as "the use of visual representations to improve the creation of knowledge and the transfer thereof between at least two persons" [5, 9]. The concept lies at the intersection of the fields of knowledge management and visualization. In education, the essence of the educational assessment process requires knowledge to be communicated (transferred) by means of academic writing. This, then, is where knowledge visualization may play a role. Knowledge visualization's goal is that knowledge can be better accessed, discussed, valued and generally managed [9].

Any study of knowledge visualization can benefit from findings from the more established fields of information- and data-visualization. Data visualization is the use of a visual representation to gain insight into an information space supporting the transitioning of data to information [7]. Information visualization supports pattern identification and knowledge creation [6]. Knowledge visualization's primary aim is knowledge transfer. Burkhard [5] provides a discussion on the essential differences between data, knowledge and information

[1] http://chi2014.acm.org/authors/video-previews

[2] http://editorsupdate.elsevier.com/issue-29-march-2010/graphical-abstracts/

visualization, as summarized and supplemented with examples in Table 1 .

We believe visualizations could be useful in supporting assessment for two reasons. The first is that it helps the assessor since the visualization is a coherent unit, presented in a format that the human brain prefers to process. It is visually available and provides a launching pad into the dissertation as a whole. The second reason is that it provides evidence of student understanding and engagement. Both new and adapted visualizations appear to provide evidence of a relatively deep level of mental processing. Consider the following two approaches to coming up with visualization:

1. Create it from scratch. This requires the drawer to engage deeply with the subject matter and to come up with a way of visualizing it [7]. Rowe and Cooke [24] assessed people's mental models in a high technology workplace where a particular level of knowledge is essential to carry out tasks properly. They tested four different mechanisms and identified a strong relationship between the person's ability to produce a high quality diagram of a situation and their proven ability to troubleshoot a problem.

2. Adapt it from, or extend, another researcher's visualization. Laseau [18] argues that extending someone else's image also helps the learner to expand his/her thinking.

Table 1: Differences between data, knowledge and information visualization

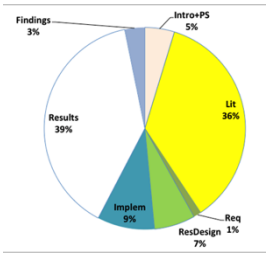
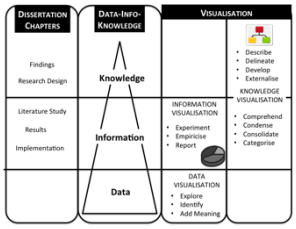
	Data Visualization	**Information Visualization**	**Knowledge Visualization**
Goal	Support Exploration of data using graphical metaphors	Support Exploration of Large Amounts of Data & Knowledge Creation	Ease Knowledge Transfer; Creation of New Knowledge
Benefit	Make data mining available to everyone, not just experts	Identification of patterns, exploration of large data sets	Augmenting knowledge transfer between individuals; communicating knowledge
Content	A large volume of data which needs to have meaning identified	Explicit data such as facts and numbers	Experiences, insights, instructions, assumptions
Answers Question	Where	What	Why, Who, How
Recipients	Data miners	Data Explorer, Pattern Spotter	Knowledge Workers
Influence	Data mining	Data analysis, Data exploration	Knowledge Transfer
Example	See Figure 2 	Depiction of an author's research areas 	See Figure 1 

Figure 1 depicts the constructs involved in information and knowledge visualization, as discussed earlier, and suggests a likely spread of information and knowledge visualization in a dissertation.

Appropriateness of Visualization in this Context

The surveyed literature on assessment did not reveal any studies of the explicit use of information or knowledge visualization in postgraduate assessment. This omission is probably an oversight and deserves consideration. A number of studies explain that humans have innate visualization processing abilities. For example, Ungerleider and Haxby [27] point out that visual processing is the most richly represented sensory modality in the human brain.

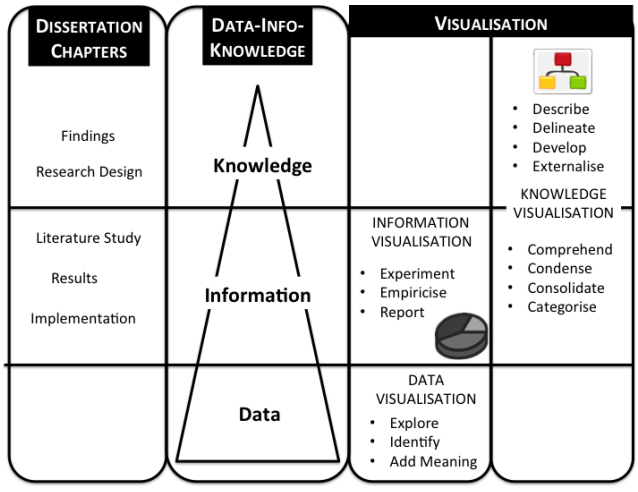


Figure 1: Mapping Visualization to Chapters and the DIK Pyramid

Reading relies on the same visual areas, but requires additional processing and cognition, and is more resource-intensive. Bauer & Johnson-Laird [2] carried out empirical studies and showed that visual representations were superior to verbal sequential representations when people carry out tasks, which suggests that the visual representation is easier for people to understand. The basic rationale behind the visualization of information is to provide a means for people to spot and identify patterns since humans have been known to be better than computers at identifying visual patterns [8, 14]. Visualizations are innately superior to text in depicting boundaries, arranging and ordering concepts and therefore conceptual frameworks can only benefit from visualization [10, 21]. There are superior memorial effects too: visual recall seems to be more reliable than verbal recall, which suggests that a visualization should "stick" longer than verbal descriptions [15].

The use of visualization needs to be guided by some assumptions and delineations. Machanic [20] warns that imposing technology between the teacher and the students can create a barrier, and that is a real concern in the use of visualizations. Therefore it has to be stated that the intended focus of visualization is the cognitive activity of representing knowledge while the technology is merely the tool and should not be given overdue attention or used for obfuscation. There is also the argument that the learning styles i.e. the visual, kinesthetic and aural [11] are based on individual modal divisions and may impact on the learning that will result from this process. That is generally beyond the scope of this study where we investigate the impact of knowledge visualizations, but we will return the argument in the discussion.

3. METHODOLOGY

3.1 Research Questions

The meta-research question that motivated this study was: "*What is the use and usefulness of visualization in postgraduate assessment?"* This broad investigation goal was translated into specific research questions:

- How prevalent are visualizations in masters' dissertations (total number and position)?
- Did the use of visualizations correlate with the final mark?
- How do examiners see the role of visualization in assessment?

3.2 Research Context

The postgraduate supervision capacity in the School of Computing has changed drastically due to rapidly increasing student numbers. In June 2010, there were 88 registered masters and doctoral students; in June 2011, there were 131; while in June and in November 2012, there were 197 and 226 students respectively. Over the same period, supervision capacity increased marginally, but nowhere near the more-than-doubling of the student numbers since 2010 [29]. Dissertations in Computing may include tables, diagrams and visual images of equipment or participants, but photos, since they are rarely used, were excluded from the analysis. It should be noted that knowledge visualizations (tables and figures) were not incentivized or explicitly rewarded at this institution. Furthermore, we could only evaluate Masters Dissertations since we wanted to explore impact on final grade and doctoral studies are not awarded a final mark at this institution.

3.3 Research Approach

The methodology entails a mixed-methods approach where the analysis of the quantitative data allowed us to identify pertinent issues regarding visualization usage. Twenty-two master's dissertations in Computing from the University of South Africa were obtained through the university's official website. The site hosting the dissertations is open and no permission is required to use the dissertations for academic purposes. Ethical clearance was obtained to access the students" marks, which we needed to investigate correlations between the number of visualizations and the final mark. The first step was to analyze the dissertations to categorize and tally the visualizations (figures and tables). To answer the first question, namely 'How is visualization used in master's dissertations (frequency and positioning)?', the number of visualizations in specific sections of the dissertation were tallied. The section categorization was based on the categorizations of evaluation report for masters' dissertations in Information Systems from the University of Pretoria, the Tshwane University of Technology and the University of South Africa. Identified sections were: Introduction, Literature study, Requirements, Research Design, Implementation, Results and Findings. (Note that the Requirements and Implementation chapters were not relevant to all research designs but were retained so as not to obscure the results in the other categories found in most dissertations.)

The second question concerned the possible impact of visualization on the final mark. To answer this question, the correlations between the total number of visualizations in each of the sections, and the final mark, were calculated.

The third question relates to the examiner perspective with respect to the role of visualization in assessment. We interviewed 12 experienced examiners and asked them to complete a short questionnaire which asked about their supervision experience, their expectations related to the use of visualization by their students generally, and specifically on the role of visualization during assessment.

4. RESULTS

4.1 Dissertation Analysis

We analysed 22 dissertations in Information Systems (IS) (a sub-discipline of Computing). There were 10 male and 12 female students representing 73% of the masters' dissertations submitted to the institution in the 2002 to 2012 period.

There were no dissertations without figures and only two without tables. The sum, minimum and maximum number of figures and tables are given in Table 2. The dissertations averaged 29.64 figures and 18.59 tables.

Table 2: Summary statistics

	Figures	Tables	Total
Sum	652	409	1061
Min	3	0	3
Average	29.64	18.59	48.23
Media	25.5	15.5	41.5
Modus	21	0	38
Max	87	48	120

The numbers are clearly too small for any analysis to deliver statistically significant results. However, it does seem that visualizations were provided by all candidates and, indeed, used frequently in many cases. Figures were used more often than tables. Having ascertained that visualizations were indeed used, the next step was to consider which sections they appeared in. The average, maximum and minimum per section is depicted in Figure 2 and the spread of visualizations across the dissertations is shown in Figure 3.

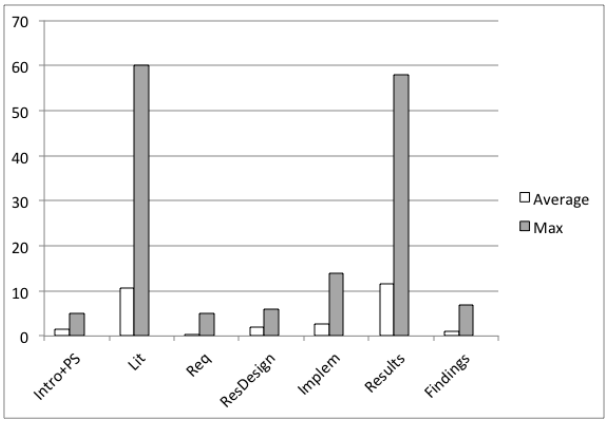


Figure 2: Maximum and Average numbers of Visualizations in Generic Sections

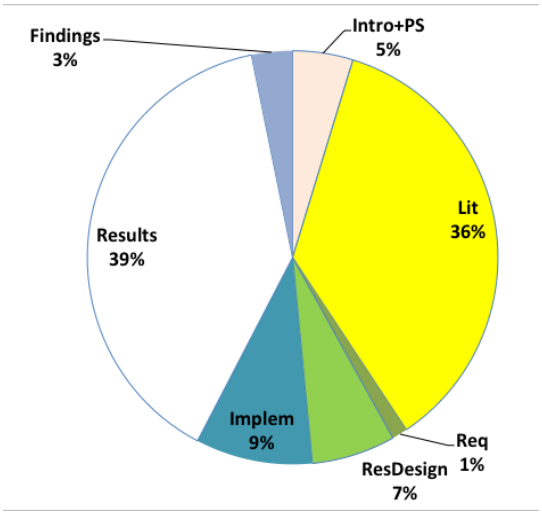


Figure 3: Spread of visualization across the dissertations

Table 3 shows the correlations between the final grade and the number of visualizations in the relevant chapters. The negative correlation of -0.107 between the total visualization count and the students' final marks suggests that gratuitous use of visualization could detract from the perceived value thereof, as judged by the final assigned grade. Moreover, depictions of existing diagrams, (-0.238), often found in the literature review, or information visualization, as found in the results section (-0.08), do not seem to impact the final mark to any great extent. However, the number of visualizations in the research design and findings sections correlates modestly with the final mark. This may imply that knowledge visualization was more useful and meaningful to examiners when they appeared in these chapters. It is possible that the examiners subconsciously used these as evidence of mastery or knowledge contribution.

Table 3: Correlations between Final Mark and visualizations in different sections

	Visualization (Total)	Literature Review	Research Design	Results	Findings
Mark	-0.107	-0.238	0.38	-0.08	0.40

Given the small sample of 22, we can only identify these trends as a topic for confirmation or rejection through further investigation. Figures 4 and 5 depict the correlations between the candidate's final mark and the visualization in a specific section of the dissertation in a bubble diagram.

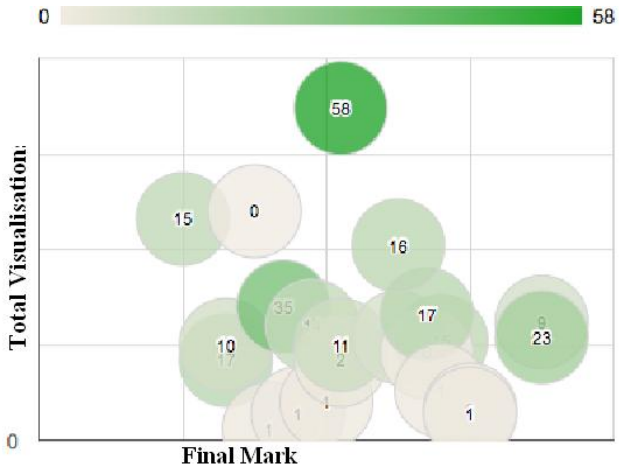


Figure 4: Final mark versus total visualization. Bubble depicting visualizations in the **Results** Chapter. (These are mostly information visualizations).

Note that the negative correlations (*Literature overview* and *Results sections*) as depicted in Table 3 occurred where the visualizations were *information* visualizations or a mixture of information and knowledge visualizations. Figure 4 depicts the individual dissertation's visualization in the Results sections. The positive correlations occurred where the visualizations were

mostly knowledge visualizations appearing in the *Research Design* and *Findings* sections, as shown in Figure 5.

Visualizations in the research design section resonate with the use of conceptual frameworks in postgraduate dissertations as advocated by Leshem and Trafford [19]. Kiley and Whisker [13] introduced the idea of generic doctoral-level threshold concepts to provide a framework for research learning and teaching at graduate level. Could constructing visualization demonstrate threshold crossing? The practice of constructing a conceptual framework is, first and foremost, for the student's benefit. It seems as if structuring and sense-making of the abstract and theoretical process in terms of a conceptual framework that can be visualized is generally rewarded in the final mark. The same argument might explain the positive correlation between the findings section and the final mark. In the next section we considered the supervisors' view on the use of visualization in masters' dissertations.

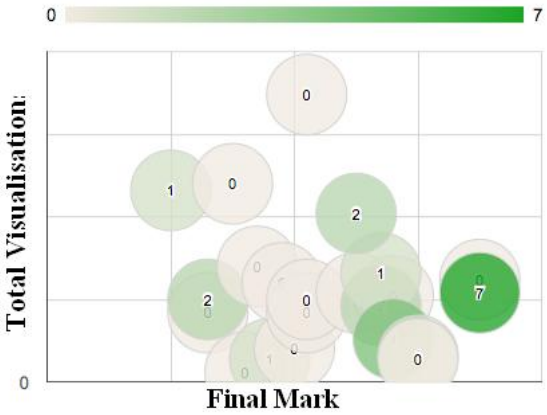


Figure 5: Final Mark versus Total Visualization. Bubble depicting visualizations in the **Findings** Chapter. (Note that these are ***knowledge*** visualizations)

4.2 Feedback from Supervisors

All twelve of the interviewees had supervised masters' students to completion and examined masters' dissertations (half had supervised more than 5 students). The participants all encouraged their students to use visualizations, 10 always did so, 1 often and 1 sometimes (no one responded with "rarely" or "never"). When asked if they appreciated the presence of knowledge visualizations when assessing dissertations: 10 answered "yes" and 2 responded with "sometimes". Table 4 depicts the number of supervisors who would encourage visualization in the given dissertation section together with their motivations as to why they believe it to be useful.

Table 4 : The parts of the dissertation where respondents encouraged visualization

Section of the dissertation	Yes	Comments on when appropriate
Introduction and overview	5	To give an overview of anticipated structure; In presenting a thesis map; Chapter map, indicating sequence and interrelationships
Literature review	9	Outline + scoping of environment; To demonstrate connection of theory; Tables and figures which explain an overview of a country's or continent's data; In summarizing the literature; More in the form of a table to summarize and compare themes. Often also repeating one or more models proposed in the lit, especially if they were going to be used later. To show an overview of essential concepts
Research Design	8	To show flow of research; To give an overview of anticipated structure; Definitely-especially a visual explanation of the research methodology is important. Also how the different terms (epistemology, theoretical framework, methodology and methods) are interrelated; Research process, summarizing methodology
Presentation of results	12	Almost always; Definitely-revisit methodology and show how the results address the different aspects for the methodology; In summarizing results; Graphs where appropriate and other forms such as time lines, networks with indications of relationships; Just charts and graphs
Presentation of findings	10	Summation of findings; Almost always some need; If more "sense making" required to help reader; Results and findings especially if qualitative; In summarizing findings; This may be building or confirming a model. To check a coherent framework and findings; Just charts and graphs

Considering the comments as provided in Table 4 it can be concluded that the visualizations in the *introduction* and *conclusion* sections constitute "good practice" as far as writing scientific reports is concerned but one does not expect to see new knowledge reported in either of these chapters – only a summary or a précis thereof. Knowledge is presented within the body of the dissertation and that explains the relatively low number (42%) expecting visualizations in the *Introduction* and *Overview* sections.

Regarding the *Literature Review* section, 75% of the examiners expected visualizations. Visualizations situated there could be very useful to the examiner. For example, the student performs a literature review, which mines the relevant research

literature. The writer of each of the sources contributed new knowledge to the field but to this particular student this is information, to be understood, consolidated, synthesized and presented in a coherent format. A good student may well produce new knowledge in this chapter, perhaps in the form of taxonomy or a consolidation from a novel perspective, but that is unusual and certainly not expected. Interestingly, the dissertation analysis yielded a negative correlation between the number of visualizations in the literature review and the final mark. It could be because the visualizations included here often replicate other researcher's visualizations thus do not represent knowledge acquisition by the candidate.

All the interviewees expected to see visualizations in the results section, which concurs with the distribution we observed in Figure 2 but not with the negative correlations between visualizations and the *Results* section as depicted in Table 3. The explanation might be that the results are not yet knowledge – they represent information that needs to be conceptualized and reflected upon. Visualization thereof, perhaps in the form of a graph, with an interpretation thereof, could constitute knowledge, and this is usually reported in the findings chapter. The majority of respondents expected visualizations in the findings chapters, this concurs with the positive correlations between the visualizations in those sections and the final mark (see Table 3) but the analysis of the dissertation revealed a relatively low number of visualizations (Figure 2) and this could be of interest for supervisors.

Finally there is the question about the negative correlation between visualizations and the final mark, as depicted in Table 3. Could it be that the quality of the visualizations was not acceptable – or did the visualizations demonstrate the student's lack of understanding, or could it be that the students used visualizations instead of text, or replicated other authors' visualizations? There could be a number of factors involved but besides the effort involved for the student, there seems to be little argument against including visualizations as a mechanism of knowledge representation in postgraduate dissertations. A further investigation using a bigger sample to conduct a deeper investigation into expectations related to the use of visualizations and the other factors that could influence this correlation is necessary.

5. DISCUSSION

This research addressed three questions: In response to the first question, related to the prevalence of visualization, we can confirm that visualizations, in terms of figures and tables, were often used, with a preference for figures. Visualizations were not explicitly assessed by this institution, and hence probably not incentivized.

The second research question was related to the usefulness of visualizations. We found that the candidate's final mark was correlated, albeit weakly, to the particular section where visualizations appeared. A positive correlation was found between the final mark and the number of visualizations in the research design chapter and in the findings chapter. The correlations do not imply causation but this finding might well motivate further investigation. Speculating on possible explanations for this correlation we consider the following aspects.

The first is that the assessor was subconsciously rewarding knowledge visualizations in the research design and findings sections. If this were the case it could be that such visualizations make it clear to the assessor what knowledge was being reported, without their having first to read through pages of text. The visualization could be providing a précis, a quick and powerful overview of the text. If this is true, the assessor gets an informative aid, something that allows them very quickly and easily to get a sense of what is being reported.

The second possible explanation could be that the visualizations are evidence that the student has indeed mastered the work. In crafting the visualizations, the students reach a deeper level of understanding of the topic area, and this was reflected in the quality of the whole report. If this were true, the quality was a side-effect, a consequence of their delivering the visualizations. As noted before, there is the argument that learning styles are based on individual modal divisions i.e. the visual, kinesthetic and aural [11] which may well impact on the learning. However, whether the visualization is a medium or an artifact, there does seem to be a positive impact of the student spending time crafting and including one or more knowledge visualizations in their dissertation.

There is clearly a proviso: that visualization should be used with care. If used appropriately, they can impact the mark positively, but mindless inclusion of visualizations could depress the final mark. The challenges pertain to the type of visualization, as well as the distribution of visualizations. Regarding the type of visualization, we observed that many visualizations were mere reproductions that added no value except, perhaps, the aesthetic. The negative correlation (albeit small) − between the total number of visualizations and the mark – could confirm the argument that the mere presence of visualizations does not automatically improve the candidate's final grade: it has to be done thoughtfully and be a meaningful artifact that supports assessment.

In summary, we conclude that, given the innate human ability to understand and remember visual representations, the considered inclusion of visualizations could support objectivity, consistency and fairness in assessment. It could also help students to engage more deeply with the subject matter, reaching a deeper understanding thereof, in the process of producing the visualizations.

In practice this means that we should consider instructing candidates to include specific standard visualizations such as a chapter map, a literature overview diagram and a visualization of their conceptual framework. This could support efficient assessment by allowing triangulation with the traditional text-based assessment. The use of visualization admittedly poses risks. The risks could be both designer- and user-induced and

relate to cognitive, emotional and social human aspects [4]. Hence the promotion of the use of visualization in research reporting should be based on validated guidelines and standards. Kelleher and Wagener [12] provide useful guidelines for effective data visualization in scientific publications but those guidelines need to be refined and customized for dissertation knowledge transfer.

Furthermore, visualizations are proposed as a mechanism to *complement* other assessment criteria, never as the sole assessment artifact. Finally, the fact that the surveyed examiners recommended the use of visualizations to their own students and expected to see them in the dissertations they examined seems to suggest that visualizations are already making their way into dissertations. At the moment it seems to be dependent on the whim and preference of the supervisor. If, as we believe, visualizations can be helpful to both student and examiners, it is necessary for us to formalize their inclusion and to provide more guidance to all students in their production.

6. CONCLUSION

Despite the potential of visualizations for improving knowledge transfer, there is little evidence of the deliberate use of visualizations to improve the efficiency of assessment. We considered the use and usefulness of visualizations in postgraduate assessment and conclude that the use of visualizations in adding value: for the student, the examiner and the final mark, warrants further investigation. Arguably the appropriateness of visualization usage may be related to the subject area, but the general benefits of visualizations in knowledge generation and transfer are not related to a specific subject area. No comprehensive guidelines on the appropriate use of information and knowledge visualizations in postgraduate dissertations seem to exist. If these can be fashioned, then visualization could well be an efficacious assessment aid. This is the discourse we would like to propose for further debate.

7. ACKNOWLEDGMENTS

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E-textbook Usage by Lecturers: A Preliminary Study

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ABSTRACT

E-book readers allow books to be read anywhere and at any time. Although these devices have been around for a long time, they have only recently become popular. The advancement of e-reader technology and students' demand for flexible content has resulted in the development of e-textbooks on e-readers. As the technology is relatively new, little research has been carried out in this area. This study investigated the reported use of e-textbooks by lecturers at a private university. The findings indicate that the lecturers are negative about the use of the e-textbooks for reasons such as technical difficulties, lack of skill, difficulty in integrating them into their teaching, the poor interface and the time required.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education.

General Terms

Performance, Experimentation, Human Factors.

Keywords

E-books, e-textbooks, lecturers, university, UTAUT.

1. INTRODUCTION

The electronic book (e-book) has seen tremendous growth; in 2009 global revenue from e-books was US$1,420 billion, rising to US$10,924 in 2014, with an expected growth of more than double the 2013 value by 2018 [22]. E-books are electronic books that are read on a screen, but are more advanced than printed material that has just been scanned [18]. The increased availability and affordability of mobile devices, together with wireless networks, has made access to e-books possible wherever an internet connection exists [9]. Although e-books are read mostly for leisure purposes [5, 9], the increase in the number of suitable e-readers has meant that textbooks are now being offered in the form of e-books [2, 5]. This is being stimulated by students' expectations that content be offered over various media [17] as well as economic pressure [5]. However, the acceptance and usage of e-books, by both students and lecturers, is not unanimous, nor without difficulty [2, 5, 9, 12].

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2. THEORETICAL BACKGROUND

2.1 Printed Books and Textbooks

Higher education has used printed textbooks for many centuries. They are vital for teaching and learning, and lecturers select textbooks based on suitability, relevance and usefulness for students, assuming that students will engage with the content for learning [1]. [1] suggest that a student's interaction with a textbook depends on the lecturer's use of the book and, if weakly recommended, the student will not purchase or use it. Hence printed textbook usage is declining. Other causes are cost, weight, static content, an entire book is not required, the minimum required is read, and content is now available from anywhere [1].

2.2 E-books and E-textbooks

The first e-readers of the 1990s were unsuitable as they were difficult to browse and navigate and caused eye strain [3, 9, 12, 18]. From 2002, electronic text books (e-textbooks) started providing content anywhere, at any time [27]. Technological development allowed the early Sony e-readers in 2004 and 2006, the Amazon Kindle in 2007 and Apple's iPad in 2010 to provide better resolution [9, 18], better navigation and the ability to highlight and annotate [18]. According to [2, 3, 8, 9 and 18], the advantages of e-books include ease of downloading, less cost, easier browsing and annotating, the use of built-in dictionaries, quicker, more efficient updating, portability, integration with other multimedia and the ability to download segments. However, the disadvantages include the expense of e-readers, reliance on battery life and an internet connection and technical issues can prevent access [3, 4, 9, 12, 21].

2.3 Students, Lecturers and E-books

As students are seen as "early adopters" of technology [13, 17], they have been the target sample of many studies as to their acceptance and use of e-books [5, 8, 9, 11, 12, 13, 24]. The results of these studies suggest that most students prefer printed books for studying [11, 12], e-textbooks are difficult for academic work [24], being online is distracting [12], reading from a screen takes longer and is more difficult [5, 12], technical difficulties [8, 12, 13], students need assistance to find books [9, 11] and pagination

is an issue [5, 8, 12]. The major advantages are convenience due to portability [8, 9, 11, 12, 13] and cost [8, 9, 11, 12].

However, less research has taken place on lecturers' acceptance and usage of e-books. [2, 3, 4, 6, 12, 19 and 26] found that lecturers prefer printed books for both teaching and research. [3] found that lecturers were unsatisfied with e-books; they found them tedious, time-consuming, difficult to use and unreliable to access, yet were not averse to using e-books if the issues were resolved. [3, 4 and 12] found that lecturers would recommend e-books if they are accessible and of good quality; this recommendation is a predictor of the use of e-textbooks by students [3, 4, 8]. The cost of e-textbooks can be a disadvantage or an advantage [3, 4, 6, 9, 12, 19]. Lecturers emphasise that e-textbooks should be supplementary to other teaching material [12, 26], while the ability to walk around with a device, while still engaging with the material is a major advantage [10].

2.4 E-Readers

Most studies involving e-books and e-textbooks have been on e-books as part of library e-resources as opposed to e-books on e-readers. [3, 8, 9, 13, 18 and 24] incorporated e-readers into their studies, but all involve students and not lecturers. The limited research is because the current e-readers (or tablets) are relatively new and, although many drawbacks have been removed, there are still challenges in using e-textbooks on e-readers, such as a critical mass of academic books, multiple incompatible platforms leading to purchasing and access difficulties across multiple devices despite the portability, eye fatigue, pagination issues, lack of training in using the devices to teach [4, 6, 9, 12, 18, 21, 26].

Although lecturers hold similar views to students about e-textbooks, the fact that students are influenced by lecturers' recommendations [1, 4, 8] suggested that research should take place into the acceptance and usage of e-books on e-readers and/or tablets by lecturers.

2.5 Theoretical Constructs

To carry out this research, the Unified Theory of Acceptance and Use of Technology (UTAUT) model developed by [25] was used. This model helps explain an individual's acceptance and/or actual usage of technology. The UTAUT constructs are as follows [25]:

Performance Expectancy (PE): the degree to which an individual believes that using the system will help achieve gains in job performance [25]. This study sought to investigate how the use of e-textbooks is perceived to affect lecturers' performance in lectures as well as their productivity and effectiveness.

Effort Expectancy (EE): the degree of ease of use of the system [25]. This study investigated the extent to which lecturers were trained to use e-textbooks and whether usage affected their lecturing.

Social Influence (SI): the degree to which an individual perceives that important others believe he/she should use the system [25]. This study looked at whether the lecturers' use of e-textbooks was influenced by their use by others and in society.

Facilitating Conditions (FC): the degree to which an individual believes that the infrastructure exists to support the use of the system [25]. This study explored whether organizational and technical conditions influenced the use of e-textbooks and whether the necessary support mechanisms were in place.

3. RESEARCH METHODOLOGY

The respondents for this study were undergraduate lecturers at a private university mandated to use e-textbooks on tablets as a complete replacement of traditional textbooks. Although all 150 lecturers in five faculties were invited to participate, only one lecturer from each faculty was interviewed. The exception was the Information Technology (IT) Division, where two lecturers were interviewed, as this division has been at the forefront of the e-textbook implementation. The small sample chosen was to select the most appropriate subjects for the study, to obtain the most pertinent information and to acquire a deeper understanding of the issues [14]. A total of six lecturers were interviewed. To ensure confidentiality, pseudonyms were used. The age range of respondents was 25 to 50 and their experience from 1 to 25 years.

A qualitative research methodology was chosen as it facilitated an understanding of the issues being faced during the transition to using e-textbooks and because there are few models that have been tested and applied in this new area of research. Semi-structured interviews were used with the questions adapted from the UTAUT theoretical framework. While the questionnaire developed by [25] was used to elicit quantitative data, other studies have utilised it in a qualitative form [20]. A content analysis was used to analyse the interview data. The findings are presented below.

4. FINDINGS

It was predicted that all respondents would see the e-textbook transition as positive, however this was not confirmed. Rather it was found that lecturers exist on a continuum with some lecturers using and promoting e-textbooks *"…the concept is really wonderful … lecturers must be encouraged…"* (Saul-Commerce) and others expressing extreme dislike of the initiative *"…e-textbooks are terrible as they are useless because the interface is terrible, the way the system operates is terrible, and, sometimes it's slow, it takes long to load the book…"* (Tim-Science).

Each construct from the UTAUT model with the related questions and findings are as follows:

Performance Expectancy determines the extent to which a particular system would improve or enhance job performance [25]. Respondents were asked to (q1) *explain whether using an e-textbook helps you accomplish tasks more quickly and if so, why?*, (q2) *describe whether using an e-textbook improves your job performance and if so, how?*, (q3) *explain whether the use of e-textbooks affects your productivity and* (q4) *describe whether using an e-textbook enhances your job effectiveness*.

Q1: Some lecturers believe e-textbooks positively impact the speed and efficiency of their lecturing. Paul (IT) feels that e-textbooks are *"convenient because I don't have to copy from the book and write on the board"*. Gareth (Pre-Degree) concurs that e-textbooks *"help me complete tasks more quickly ... quickly use the search ... makes it faster ..."*. Tim (Science) disagrees as he cannot "*copy and paste from the e-textbook"* which means that *"I still have to type everything"*. Additionally Yasmin (IT) feels that the promise of greater efficiency has not been realised "*… internet dependent and we have very limited access ... my experience has not been very positive".*

Q2: It was apparent that the use of the e-textbooks does not automatically improve an individual's job performance. The e-textbook *"does not improve my performance ... and it takes so much time and an undesired amount of effort"* (Naomi-Arts). Tim (Science) agrees *"the interface is terrible ... it's difficult"* while Paul (IT) mentions *"if my device doesn't have power then I am no longer doing my job"*. The fact that e-textbooks are relatively new may account for the negativity, Yasmin (IT) suggests that "*if the book is used properly then it's very interactive ... something that goes beyond what we do in the classroom…. it will change the way we deliver modules".*

Q3: Lecturers were not convinced that using e-textbooks improved productivity *"I expected it to already have made a change and it didn't"* (Yasmin-IT), *"negatively affected my productivity ... difficult to teach using e-textbooks because it takes longer"* Gareth (Pre-degree). According to Naomi (Arts) e-textbooks negatively affect teaching time and impact on productivity *"if I want to reference another page I need to remember where it was located and then scroll to find the page ..."*.

Q4: Lecturers were more positively inclined to use e-textbooks depending "*on the task at hand, if I want to make reference to the page, I can use an overhead projector to show the students"* (Naomi-Arts); "*sometimes I use slides ... I can just copy and paste from the e-textbook ... it is easier to use"* (Saul-Commerce).

Effort Expectancy is the degree of ease associated with the use of a particular system [25]. Within this construct, respondents were asked to (q5) *comment on your experience whilst learning how to use an e-textbook*, (q6) *describe how using an e-textbook affects your teaching*, (q7) *describe how you interact with an e-textbook and* (q8) *describe your skill level around using an e-textbook*.

Q5: Paul (IT) feels that using books and e-textbooks are similar *"... the only difference is that e-textbooks depend on the software"*. Tim (Science) however feels that the experience *"was terrible and I am still learning how to use it... the interface is terrible, the way you browse is terrible"*. For some, the issue is time *"learning to use e-textbooks takes time ..."* (Yasmin-IT).

Q6: It was evident that alignment with pedagogical approaches impacts how the e-textbooks affect teaching. Naomi (Arts) *"mainly uses it for demonstration purposes*", while Tim (Science) feels that he is able to engage more with students as *"it allows me to connect the tablet and then I can project onto the screen".* Paul (IT) concurs and feels that using e-textbooks *"makes my teaching much better as it allows me to hold the device and then walk around the class and interact with my students"*. Preparedness was also mentioned as a factor influencing lecturers' experiences. Yasmin (IT) feels *"if I am not prepared ... it will affect my teaching ... I will be trying to search and teach at the same time"* whereas Gareth (Pre-Degree) feels that technical preparedness is essential *"I always make sure mine is fully charged ... otherwise my lecture time will be wasted".* Gareth (Pre-Degree) feels that the students also need to be prepared *"... they neglect to come prepared then it affects the way I teach".*

Q7: Tim (Science) says *"... creating PowerPoint slides and preparing for class"*. Saul (Commerce) concurs *"... to prepare for class, to make sure I know where to find the information that I need".* Motivation also influences lecturers' interaction *"I have been against using an e-textbook, so honestly I do not interact with it often"* (Naomi-Arts) whereas those lecturers that are positive feel that they *"interact with it more often ... in the planning phase, writing the study guide and so on"* (Yasmin-IT).

Q8: Lecturers feel that they lack sufficient skills "*I am still a novice"* (Yasmin-IT); "*I am moderately skilled"* (Naomi-Arts); *"my skill level is very low"* (Tim-Science). Paul (IT) feels that the lack of time using e-textbooks may contribute to the lack of skill *"I'm not highly skilled since I'm not using it every day";* Gareth (Pre-Degree) concurs *"I am 50% there because I don't use it so much".*

Social Influence is used to determine the extent of a person's perception of others' [25]. Within this construct lecturers were asked to (q9) *explain whether anyone around you influences your use of an e-textbook and* (q10) d*escribe whether people around you use e-textbooks*.

Q9 and 10: Some lecturers feel the mandatory use of e-textbooks is the most compelling influence, however different motivations between faculties were evident "*in our faculty it's actually forced"* (Tim-Science), whereas Yasmin (IT) feels that in the IT faculty *"some do and some don't"*. Other lecturers feel their use of e-textbooks is their own choice and not due to mandated requirements *"I wouldn't stop using it now because everyone else is not using it, no"* (Yasmin-IT) "*it's not influenced by my peers, I have just decided to use it because of my convenience"* (Saul-Commerce). Peers were also mentioned as an influencing factor "*as we progress I feel that I am swayed by my peers ... we are trying to come to a point where we are all using e-textbooks"* (Gareth-Pre-degree). Finally, lack of planning and the initial failure of the initiative was cited as an influencing factor *"our initial*

project didn't go well" and even though *"more training and more back up and more internet connections have been provided, people are not really using it"* (Yasmin-IT).

Facilitating Conditions is the extent to which an individual believes there is the organisational and technical infrastructure to support the use of a system [25]. Within this construct, lecturers were asked to (q11) *describe the resources, training and extra support provided to you while using an e-textbook*.

Q11: Most of the lecturers highlighted training as the most important factor. Even though training was provided, it was inappropriate *"training was really on the device ... but not how to teach using the e-textbook"* (Tim-Science). Yasmin (IT) highlights that *"... training was mostly on the device so in my opinion there is still a gap"*. Lecturers had hardware issues *"we were not given the cables that we can use to project ... so they expect us to teach using the e-textbook but there were no cables"* (Tim-Science). Finally, the lack of ongoing support of lecturers using e-textbooks *"extra support is really just me researching and teaching myself"* (Gareth- Pre-Degree) is an issue affecting the use of e-textbooks at the university.

5. ANALYSIS OF RESPONSES

An analysis of the lecturers' responses suggests the following:

Performance Expectancy: The lecturers in this study are split in their opinions. Some lecturers feel that e-textbooks help them accomplish tasks quicker with more convenience, whereas other feel that they depend on the internet and the software has limitations. This lack of fit between the software and lecturing is consistent with previous literature which found that if the technology and software do not allow the user to perform their job properly, the user will neither use, nor feel positive about using the software or technology [4, 6, 9, 12, 21, 24]. It was also found that the introduction of e-textbooks and their mandated use does not guarantee an improvement in job performance. Lecturers cite their lack of proficiency; the tedious nature of using the software; the poorly designed interface; lack of reliable connectivity; lack of alignment between e-textbooks and lecturing; and technical issues as reasons for their lack of performance whilst using e-textbooks, which confirm the results of other studies [3, 4, 6, 12, 21].

Effort Expectancy: The lecturers have found the transition challenging and are still not comfortable using e-textbooks; some have found the transition so onerous that they have reverted to traditional textbook approaches. The reasons cited were the difficulty using the e-textbooks to lecture which may be a function of time engaging with e-textbooks. [1] state that the amount of time spent interacting with a new technology influences one's willingness and ability to use it. Some lecturers feel that they will become more skilled with more engagement with e-textbooks. Lecturers feel that both students and lecturers need to be well prepared for lectures. The lack of preparedness is a possible reason for the low uptake of e-textbooks as lecturers feel this leads to wasted time. This is consistent with the findings from [3 and 10] which state that preparation is vital. Attitude and interest in using and engaging with e-textbooks were found to influence lecturers' perspective on the effort required. This is consistent with research by [2 and 6] which state that if people are not willing or ready to accept change, their experience will not be positive. Finally, the need by lecturers for alignment between the software and their lecturing is consistent with previous studies that found that software can affect an individual's experience and subsequent use [4, 12, 21, 24]. Lecturers feel that using books on mobile devices allows them to walk around and involve themselves with their students [10].

Social Influence: Most lecturers do not feel influenced by their peers' use of e-textbooks, consistent with [7], but are using them due to the university's mandatory policy. Previous research has found that this construct is affected by whether or not the individual has volunteered to use the technology [7, 15, 23].

Facilitating Conditions: This is the major negative factor in this study. Facilitating conditions are important predictors of technology acceptance and may be a barrier to usage if these conditions are not satisfactory. This confirms previous research [3, 4, 12, 15, 23].

Research into the acceptance of technology has used the demographic variables of age, gender and experience to moderate the factors that influence the acceptance of technology [7, 15, 23]. These were found to be insignificant in the current study.

6. CONCLUDING REMARKS

6.1 Limitations and further research

The limitations of this study are, firstly, the sample size is small so the views do not reflect those of other lecturers or other universities, and the findings are therefore not generalizable. Secondly, the data was collected through interviews which rely on self-reported behaviour, which may not reflect actual e-textbook usage. To gain more generalised findings, this study could involve more than one lecturer from each faculty and be carried out at multiple South African universities. In addition, to ascertain whether time will positively influence lecturers, a longitudinal study of the usage by the same lecturers could be carried out.

6.2 Conclusion

This study set out to investigate the reported use of e-textbooks by university lecturers at a private university. To this end, a modified IT acceptance model was used to suit the qualitative nature of this study. Few lecturers have adapted to using e-textbooks and it emerged that an individual's performance is influenced by the task at hand and by the software. The e-textbook software has not been a success, which has negatively affected the lecturers' use of e-textbooks.

Lecturers who are more interested, use e-textbooks more often, however, there have been many challenges faced by lecturers, including lack of skill, lack of interest, lack of connectivity and lack of efficient software. These challenges need to be addressed to ensure a more positive response towards the use of e-textbooks.

Based on this study's findings, the researchers conclude that the use of e-textbooks has been negatively received, however there is still time for improvement, as e-textbooks and e-readers evolve and lecturers become skilled in the use of e-textbooks.

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How Can We Help You? Identifying High Risk 1st Year IT Extended Students

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ABSTRACT
In this paper, we describe the identification of high risk students doing an extended Information Technology course at the North-West University's Vaal Triangle Campus. A set of seven criteria was developed and used to identify academic and historic first year high risk students. The seven criteria were compiled specifically for the Information Technology Extended course. From a group of forty six students, eleven students were identified as being high risk and upon interviewing eight of them it was found that these students faced multiple hardships in their endeavour to prepare for a future IT career. The findings from the action research with no emancipation steps put in place, were used to compile recommendations of which most are within the sphere of influence of the university. The implementation of recommendations listed in this paper, would necessitate the appointment of a team of dedicated people to identify these students on a yearly basis, assess their needs and refer them to the various sections within the university that may assist them.

Categories and Subject Descriptors
K.3.2 [**Computer Uses in Education**]: Computer science education, information systems education and curriculum

General Terms
Human Factors

Keywords
High risk students, Criteria to identify high risk students, High risk student support.

1. INTRODUCTION
In their research on the review of the public Higher Education (HE) sector, which considers the flow of students in and out of higher education, Breier *et al.* [1] found that only 15% of students who enrol for a course, complete their degree in the designated time; while 50% drop out somewhere in their course.

It is important to find out why high risk students are underperforming and to find ways of assisting such students to complete their studies successfully. Lehr *et al.* [5] classified variables associated with dropouts as status variables and alterable variables. Status variables which include socio-economic standing (SES), disability or ability level and family structure, are hard to change, while it is possible to change alterable variables such as class attendance and identification with school. Alterable variables can also be influenced by educators, students, community members and parents. Alterable variables are the focus of efforts to increase school completion.

At the North-West University (Vaal Campus) students who are not qualifying to study Information Technology (IT) based on their matric results, may be considered to do an ITE course. The ITE course is designed to offer the IT curriculum over four years, instead of the regular three years. It allows for some supporting modules in addition to the normal IT modules. The study under discussion was conducted during 2014 – on first year ITE students. Students enrolling for the IT Extended (ITE) course may repeat modules. Forty six academic and historic first year ITE students were part of the group investigated.

In this study, quantitative data regarding ITE student performance was used to identify the students that may be classified as high risk students. A set of seven unique custom-compiled criteria guided this step. It was followed by interviewing the high risk ITE students to be able to gather qualitative data regarding their individual situations. The qualitative data was interpreted and evaluated to identify trends regarding difficulties – to be able to make recommendations to the university regarding supporting high risk students in general.

In the subsequent sections the following aspects will be addressed; section 2 – who is a high risk student?, section 3 stresses the importance of supporting high risk students, section 4 looks at which criteria may be used to identify high risk students, while section 5 focuses on the students who were identified as high risk. Section 6 discusses the findings and section 7 identifies the limitations to the study. The conclusion with recommendations follows in section 8.

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2. WHO IS THE HIGH RISK STUDENT?

Guidos and Dooris [3], in their research paper on characteristics of high risk students who graduate, which was conducted at the Pennsylvania State University in 2008, simply define high risk students as students that are from low income homes. Leonid and Ivan [6] defines a high risk student as one who tends to leave before completing their program (and not re-enrol later) or those demonstrating academic underachievement.

Watson [9] enumerates the social characteristics of high risk students as having delays in enrolment from high school to post-secondary school, enrolling part-time rather than full-time, being financially independent, having dependent children, being a single parent and working full-time while enrolled. He also included first generation students whom he refers to as students whose parents did not pursue higher education and are likely from a low income home [9].

In a South African context, the findings from literature are relevant since a large percentage of the population come from low income homes where parents did not have opportunities to further their education in an apartheid South Africa.

The rich picture in Figure 1 below illustrates the predicament of a high risk student.

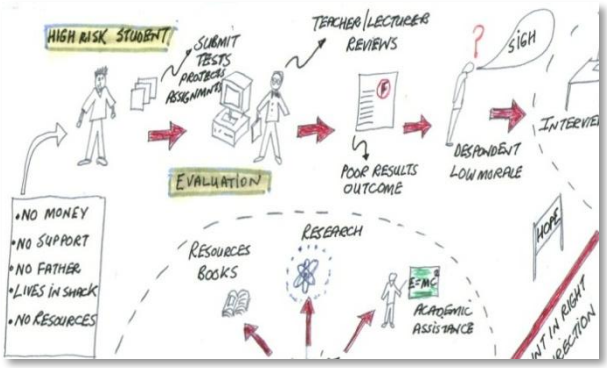

Figure 1: The predicament of a high risk student

The picture presents a high risk student facing varied challenges, such as lack of funding, lack of support and being from a single parent home.

3. IMPORTANCE OF SUPPORTING HIGH RISK STUDENTS

According to Jones and Watson, [4], it has been proposed that there should be an institutional commitment in assisting high risk higher education students. Strategies need to be developed to reduce risk and increase the likelihood of retention. Therefore attaining a degree requires commitment not only by the student but the HE institution as well.

In their research on the review of the HE, which considers the flow of students in and out of higher education, Breier *et al.* [1], found that only 15% of students who enrol for a course, complete their degree in the designated time. A high percentage of 30% of students drop out after the first year. A further 20% drops out after their second or third year.

The urgent need for improvement in retention and graduation rates in South African (SA) HE and the similarities in the challenges facing these HE contexts provide a strong rationale for the investigation of student engagement as a contributing factor to success in SA HE [7].

Decker *et al.* [2] found that relationships with lecturers are important to the high-risk student. The lecturers who are lecturing our IT extended students in the university are passionate about their students and are genuinely interested in their progress. They generally have a positive relationship with these students. In fact, one of these lecturers is the pioneer of the extended program at the university.

The number of high risk HE students dropping out of university is unacceptable. Many resources are invested into institutions by stakeholders, be it government, parents, lecturers or students themselves. When a student is not able to complete the program he/she enrols for, all these resources become wasted. Therefore, this study is very important for a university to remain a citadel of learning; it has to be able to produce a good number of graduates, continuously.

The importance of finding out why high risk students are underperforming cannot be underestimated since it allows educators to find ways of assisting them to complete their studies successfully. The rich picture in Figure 2 depicts a successful high risk student.

Figure 2: A successful high risk student

The picture presents a high risk student who overcame multiple adversities to graduate, which opens up opportunities of finding a job and allows him or her to make a contribution to the development of our country.

4. CRITERIA USED TO IDENTIFY THE HIGH RISK STUDENTS.

After careful analysis of the marks of the ITE students on eFundi – the Learning Management System (LMS), the high risk students were selected based on seven criteria. These criteria were tailor made for the cohort of students included in the study. They include the following aspects; students failing at least one test, students who did not write a test, student failing to submit two or more assignments, students failing a first opportunity examination during the preceding semester, students who failed one of their modules in the preceding semester, students not qualifying for an examination and lastly, students qualifying for an examination, but failing to write it.

(1) Students Who Failed at Least One Test

When a student has already failed one of the tests for a particular course in a semester, it was seen as an indication that (s)he has not yet mastered the already covered parts of the course contents. In addition, since most IT course concepts, especially programming concepts build on each other, it becomes tougher for the student to pass subsequent tests. This then goes on and on and eventually the

students either narrowly gets exam admission and ends up failing the course or (s)he is not able to obtain enough marks to grant examination admission. This criterion, therefore, aims at identifying these high risk students early enough so that they can be helped in good time.

(2) Students Who Did Not Write a Test

Not attempting to write a test might be due to other reasons such as illness or an emergency situation, but most often, it is due to unpreparedness for the test, which in turn might be lack of understanding of the course content. Therefore, this criterion also helped in identifying high risk students.

(3) Students Who Did Not Submit Two or More of Their Assignments

Assignments are an integral part of formative assessment which is a type of evaluation that is used to keep learners informed about his or her progress and to improve learning [7]. Formative assessments, such as assignments are important ways of predicting the future success of any student. Therefore students who did not submit assignments were included on the list of high risk students in our study.

(4) Students Who Failed a First Opportunity Examination in the First Semester

Second opportunity examinations are a way of granting students who are border-line cases another opportunity to pass their examination. It is granted to students who failed the first opportunity examination. These students were also identified as high risk students in our study.

(5) Students Who Failed a Module in the First Semester

In as much as students who qualified for second opportunity examinations fall within the category of high risk students, not passing a second opportunity examination spells failure, which is the eventuality of the high risk student.

(6) Students Who Did Not Qualify to Write an Examination

Bona fide first year students the North-West University are admitted to examinations with a participation mark of 35% and above. For all other students a participation mark of 40% and above applies. When a student fails to acquire examination admission, it actually indicates a combination of some of the criteria discussed above. Specifically, it means that the student either did not submit enough assignments; or did not write tests; or did write tests but failed the tests. Therefore the cause of multiple failures needs to be investigated in order to offer students meaningful support.

(7) Students Who Qualified for an Examination, but did Not Write the Examination

Not writing an examination, unlike not writing a test, is usually due to reasons such as an illness or an emergency situation. However some students might decide not to write an examination due to the fact that they have lost all hope of passing the examination.

This is either due to lack of understanding of the course content or lack of preparedness. Therefore, this criterion has been included on our criteria for identifying high risk students.

The seven criteria listed above, was used to identify the high risk ITE students. Unfortunately this was a cumbersome process which may prove too long to implement across all courses on a campus. It may be necessary to do some research regarding the minimum criteria necessary to still accurately identify high risk students. Another option would be to develop an artefact designed around the seven criteria, to identify high risk students electronically. This may prove useful, especially if each course would identify its own criteria.

5. SELECTED HIGH RISK STUDENTS

The participants in the study were 2014 ITE students, at the North West University's Vaal Triangle campus. A total number of eleven students were identified and eight interviewed from the IT extended group of forty six – after analysing their performance on the university LMS known as eFundi and based on the criteria discussed above. At the time of the study a ninth student had already dropped out of the course – because of financial difficulties. He was not included in the study, but in combination with the high risk students included, the analysis indicated close to 20% of students – in a fairly small ITE cohort being high risk.

It was found that most of the high risk students that were identified for the study, had two or more of the criteria as discussed above, applicable to them. This information is summarized in Table 1 below.

Table 1: Identified high risk students and the criteria applicable to them

Students	Criteria applicable	Number of criteria
Student A	1; 2; 3; 5; 6	5
Student B	1; 2; 3; 4; 5	5
Student C	1; 3; 5	3
Student D	1; 3; 4; 6	4
Student E	1; 3; 6	3
Student F	1; 3	2
Student G	3; 4	2
Student H	1; 2; 3	3

None of the eight students met only one criterion – most met more than two. Also, only the criteria applicable to student F did not include the failing of an examination or no admission to an examination.

6. FINDINGS

After the identification of the eleven high risk students, an interview was conducted with eight of them. Of the remaining three students, one had terminated his studies for financial reasons and the remaining two never showed up for the interview even after prior confirmation of the date and time. The results are discussed in the subsequent five sub-sections.

The sub-sections include all the aspects of student life, such as parental support, assignments and problems to submit, basic nutrition, prior enrolment at a HE institution and whether they made use of peer academic support – especially the help of senior students.

Parenting

From the interview, it was gathered that all the high risk students identified were from previously disadvantaged black communities. A quarter of them do not have either parent alive. Another quarter has lost only their fathers while half of them still have both parents alive. Of the ones that still had both parents alive, 12.5% do not see the father often. Half of the students live with their grandmother and half of them are being raised by single parents.

Assignments

Not being able to submit all assignments was a criterion that was found to be common to all the high risk students identified. It was found that half of the students did not have the required text book and another half said they were not able to submit all their assignments because they did not understand the content of the work. A quarter of the students felt that the time given was too short; while the last quarter said failure was due to lack of internet access. All of them said that they would have been able to submit all their assignments if they were given more time to complete it.

When asked if they do get help with assignment due date extension when they are not able to complete their assignment due to illness or work overload, a quarter responded positively and the rest negatively.

When asked if they were aware that there were resources posted to help them for each of their assignments, 40% said they were aware of this, while the rest said they were not aware.

Sustenance

Three quarters of the students were not able to afford three meals a day. Most of them said that they go hungry most days. One actually said that supper was the only guaranteed meal daily. The students said that it is particularly difficult to understand lectures delivered in the class because they do not have the required physical and mental capacity to be able to comprehend difficult concepts.

Former Enrolment

We found that three out of the eight students were previously enrolled in another HE institution with only one of them able to complete the studies. The others were not able to complete due to failing subjects and financial pressures. This corresponds with literature where Leonid and Ivan, [6] define high risk students as those who tend to leave before completing their program (and not re-enrol later) or those demonstrating academic underachievement.

Relationship with Senior Students

From all the students, five said they had senior students (peer mentors) assigned to help them with their studies, the others did not have support. Of those who said they had peer mentors three said it was easy to get help, while the others gave reasons below for not getting the desired help (see Table 2).

Table 2: Getting help from seniors is difficult

Student	Reason
Student A	not easy to get hold of the assistants
Student D	they are too fast and they like to discourage you when you don't understand so it is kind of difficult
Student E	I hardly understand what they share
Student F	afraid to approach them since they are older, though I wish to, besides S.I. only
Student G	it is sometimes hard to get hold of them since they too happen to be busy with their work

When using the classification by Lehr *et al.* [5], only one of the six sub sections discussing the problems students are facing, may be classified as a hard to change status variable, namely parenting. Although sustenance is linked to SES, it is the opinion of the researchers that it may be grouped with all the other problems to be classified as alterable variables that is within the sphere of influence of the university to change.

It is reassuring to note that the students did not mention any problems with lecturers. This supports the view of the researchers that the ITE lecturers make extensive efforts to support their students.

7. LIMITATIONS TO THE STUDY

While conducting the study two aspects limited the study, namely:

Restricted access to the LMS: After seeking permission from the lecturers, some did not grant us full access to the LMS. However, the rest did provide us with the data that we needed. The research was conducted only with the information available to us.

Difficulties in contacting students: After numerous futile attempts in contacting the students via the university's e-mail, the researchers decided to obtain their contact numbers from the university's administration and call them. It took some time to get the list of phone numbers. We made several calls and sent text messages – with only a fraction responding. Finally, we went to their classes to talk to them. That proved to be successful and we could make appointments to interview them.

8. CONCLUSION

Using unique custom-compiled criteria to identify high risk students at the North-West University's Vaal Triangle Campus, high risk students doing their first year in the ITE course were identified. After interviewing these students, it became clear that they were indeed at risk of not completing their studies.

The study highlighted that these high risk students face multiple hardships in their endeavour to prepare themselves for a future career. Little of these problems are hard to change status problems. Most are alterable problems which are within the sphere of the university's influence to change.

From the themes that emerged from our research, we made recommendations. These recommendations are summarized in Table 3 below.

Table 3: Recommendations from the study

Nr	Themes	Recommendations
1	Travelling long distance	Possibly move them to campus
2	Lack of planning	Life coaching
3	Financial problems	Provide bursaries
4	Lack of energy	Supply meal vouchers
5	Limited cubicles and high noise level in the library	Appoint student monitors / grannies Provide more study cubicles
6	Limited access to internet resources	Off the campus residences to get uncapped internet access
7	Overcrowding in the computer laboratories	Allocating time slots Appoint student monitors / grannies

Of the seven themes that emerged, the researchers would like to clarify two recommendations, namely that of numbers 5 and 7. The university's Vaal Triangle Campus is making use of pensioners, grannies – male and female, to invigilate tests and examinations. It was felt that these part-time appointments may be expanded to include monitoring the noise levels in the library (point 5) and ensuring that students using the computer laboratories have booked time slots and do university work as opposed to spending their time on social networking – especially

during busy periods (point 7). It is the opinion of the researchers that these older people would utilize a soft approach to direct students to display a courteous demeanour to their peers – by making them aware that the noise they make are not appropriate for the environment, or that they should book a session when they need to work on a laboratory computer during peak times, or that they may not be busy with personal social media interactions on a laboratory computer while another student has university work to do.

Future research may include a larger cohort of students from more than one course, more than one campus and possibly more than one university. This would enable recommendations that are universal to the unique South African situation.

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To NoSQL or Not to NoSQL: That is the Question

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ABSTRACT

In a world of big data, the term 'Not Only Structured Query Language' was coined in 1998 to describe non-relational databases and rapidly expanded in the Information Technology environment. It is commonly referred to as NoSQL. There was much debate on whether NoSQL could replace relational databases. This debate is important and will be rampant for many years to come. In the meantime, NoSQL systems cannot be neglected, as it serves an important purpose in the world of databases, big data and business intelligence. For this reason, the incorporation of NoSQL in a database systems module is crucial as it enables students to include it in their arsenal of tools needed when entering industry after graduation.

This paper reflects on a typical database systems module included in most computer science courses. At the North-West University (Vaal Triangle Campus) the course was amended in 2013 to incorporate NoSQL. This paper focuses on the implementation of a practical project assignment example with its accompanying assessment rubric – important tools to ensure NoSQL's integration with the rest of the module. It also investigates students' understanding of the underlying concepts during two years of implementation.

With the second implementation of the inclusion of NoSQL, the first implementation was improved to allow students to form their own understanding of how NoSQL environments may be integrated with traditional relational environments – instead of the lecturer doing it for them. Informal feedback from students during their project assignment presentations, as well as the depiction of their understanding of the project assignment are reflected on and considered for possible future amendments to the subject module.

Categories and Subject Descriptors

K.3.2 [**Computer Uses in Education**]: Computer science education, information systems education and curriculum

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General Terms

Design, Human Factors, Theory, Results, Evaluation.

Keywords

Education, database systems project, NoSQL data stores, dashboard, web crawler, business intelligence.

1. INTRODUCTION

In an earlier paper, the authors suggested an amendment to a typical database systems module including data models, the relational data model, relational algebra, entity relationship modelling, advanced data modelling and normalisation; by including NoSQL data models [1]. In order to integrate NoSQL in the existing curriculum the following important aspects of NoSQL needs to be covered; goal and purpose, the NoSQL data models available, the technical aspects implemented by NoSQL and the technologies available [1].

It was highlighted that practical project assignments are important in guiding students towards understanding the value of NoSQL technology. Two scenarios were stated as examples, namely a relational-NoSQL hybrid environment where the focus of a hybrid scenario slightly changes when compared to a relational-only database system – only a few features needs to be added to the typical RDBMS; and a NoSQL only environment where the implementation focuses on the NoSQL model – juxtaposed to the well-known relational model [1].

Since the amendment of the curriculum, the subject module was offered twice. In both cycles the lecturer chose to implement the first scenario of the two suggested. This is mainly due to time constraints and to ensure that students understand the integration of the two environments. The lecturer plans the NoSQL only implementation as a project assignment on a more advanced level such as a post graduate course in database systems. This paper focuses on the two implementations and the lessons learnt from it. It also looks at possible future modifications that may enhance the offering of the module.

In Section 2, this paper proceeds with a discussion on literature regarding key aspects related to the project assignments discussed. It includes clarification of terms to provide background information. Research methodology introduces the view from which this study is conducted in Section 3. This is followed in

Section 4.1 by the first implementation of the hybrid NoSQL-relational environment. In Section 4.2 the second implementation of the hybrid NoSQL-relational environment is presented. The students' understanding of the hybrid NoSQL-relational environment implementation is discussed in Section 5. Finally, the paper concludes with Section 6.

2. LITERATURE REVIEW

The following key concepts are defined for the purposes of this study: Database Management System (DBMS) and Relational Database Management System (RDBMS), Not only SQL (NoSQL), information, BI and Data Warehousing, web crawler and dashboards.

DBMSs as a concept have been developed during the 1960s. In 1970, Dr E. F. Codd suggested a new data representation structure (model), known as the relational data model. It was a revolutionary development at the time and it is still used extensively today. The new relational data model supplied a foundation for the development of several **RDBMSs** [20].

Since the 1980s, a number of other data models emerged, such as the Object-Oriented Model (OOM), developed in the mid-1980s and the Extended Relational Data Model (ERDM), developed in the mid-1990s [3, 15]. Although OOM and ERDM represented necessary developments, they were attempts, though successful ones, at improving on the relational model developed by Codd.

In the web age, the large volumes of data generated deemed conventional models ineffective. The sheer volume of data was the motivation for the development of a new model. In 1998, the term **NoSQL** was first introduced and used to describe Carlo Strozzi's open-source relational database [11]. His database did not provide a Structured Query Language (SQL) interface [11]. The meaning of the term has changed since 1998 and is widely used to describe these new NoSQL DBMSs.

The first reference to the term NoSQL after 1998 was in early 2009 in a blog written by Eric Evans, when he announced that an event had been organised to discuss open-source distributed databases [6]. As a result of the blog, the name NoSQL was used to label these new DBMSs, which are non-relational and distributed data stores. NoSQL refers to a next generation DBMS that is "non-relational, distributed, open-source and horizontally scalable" [4]. NoSQL DBMSs differ from RDBMSs since they are not built on table structures and do not provide SQL support to allow for manipulation of data [14]. NoSQL data stores support various data models that are unique and different from RDBMSs [2, 10, 14] . The main difference between the two DBMSs technologies is that NoSQL mostly stores unstructured data which are more complicated to interpret. The data stores of RDBMSs are relational and store structured data. Typical data models used in NoSQL DBMSs include key-value stores, document stores, column-oriented stores and graph databases [2, 7, 14]. Coronel *et al.* [3] state that in the current information age, the "production of accurate, relevant, and timely information is the key to good decision making". Good decisions are paramount and guide organisations towards more effective management, as well as more lucrative businesses [12].

Information generation requires data to be accurate and stored in an organised way. This process is facilitated by a discipline known as data management. Morris *et al.* [15] define data management as 'the proper generation, storage and retrieval of data'. For this reason, data management is a core activity of any organisation.

BI is obtained by transforming data into information and information into knowledge; all happening in an organisation's context. BI improves a business's performance through active decision making which empowers the user to make good decisions based on collected knowledge of the business [15]. March and Hevner [12] state that the term 'business intelligence' "refers to inferences and knowledge discovered by applying algorithmic analysis to acquired information". Morris *et al.* [15] provide a more comprehensive description of BI as "a term used to describe a comprehensive, cohesive, and integrated set of tools and processes used to capture, collect, integrate, store, and analyse data with the purpose of generating and presenting information used to support business decision making". BI is drawn from an intelligence repository known as a **data warehouse** [12]. Data warehouses store structured data. Inmon [8] describes a data warehouse as a "subject-oriented, integrated, time-invariant, non-updatable collection of data used to support management decision-making processes and business intelligence". BI, according to Rud [21], "encompasses all the capabilities required to turn data into intelligence, [and] has emboldened companies to strive for the ultimate goal: getting the right information to the right people at the right time through the right channel". As Morris et al. [15] state :

> *"BI is not a product by itself, but a framework of concepts, practices, tools, and technologies that help a business better understand its core capabilities, provide snapshots of the company situation, and identify key opportunities to create competitive advantage".*

Many of today's BI programs focus intensely on analysing data. Businesses want scorecards, dashboards, and applications driven by analytics, and the supporting technology is mature enough to deliver these tools. Although this is true, companies still struggle to deliver analytic tools with a high impact that are purposeful, insightful, and perform the actions required by business [21].

A **dashboard** is a single screen that provides a summative snapshot of the business's operations. A dashboard will display important metrics and key statistics about the business's functional areas like sales, goals, progress and flow of processes [23]. Dashboards work well for the transforming raw or meaningless data into useful information [13]. If BI requires information and information requires data, then question is; where does this data come from? Data may come from various sources including: sensor data, machine log data, data storage, public web, social media business applications media, documents and archives

[9]. Using a web crawler is one way of generating data from the public web.

Web crawlers are programs designed to follow the structure of the Web to move from one page to another. Earlier they were called wanderers, robots, spiders, and worms [19]. Some of these words remind one of a spider's web. It is important to note that the noun 'crawler' is not an indication of how slow these programs perform, since they may be very fast. Web crawlers may be used to retrieve data on web pages and store them in a repository. A simple crawler would start from a home page and then use external links to move to other pages. The process repeats in each new page where more external links are found, until the set objective is reached [19]. Although web crawlers are an essential component of all search engines, they are becoming increasingly important in data mining and applications where indexing is needed [5, 18].

3. RESEARCH METHODOLOGY

Interpretivism, which was introduced by Dilthey during the 1800's posit that it is important to understand the differences in humans' roles as social actors (Saunders et al., 2009:116). This paradigm is mostly employed by social science researchers, as opposed to Positivism, which is mostly applied by the natural scientist. In essence, Interpretivism probes beyond facts towards meaning [16]. The interpretive researcher wants to understand – enabled by using gathered data which may be used to develop a theory, supported by the data. Narratives, which are qualitative in nature, are mostly used in interpretive research. There are various techniques available for a researcher to collect qualitative data. Some of the common techniques include: interviews, questionnaires, observations and documents [17, 22].

The main aim of the researchers was to understand – to be able to inform the next implementation of the project assignment. Observations – where the researchers observed the presentation of the systems developed and the study of documents – where the researchers could probe the development groups' documentation were the techniques applied during the evaluation of the projects. In the context of an evaluation, clarifying questions could be asked. This once-off observation and study of documents were amended with the lecturer being the facilitator of the students' understanding and the person guiding them to make sense of their project assignment.

4. IMPLEMENTATION

4.1 A first implementation

The first implementation of the NoSQL project assignment is included in this study to get a full picture of the implementation, to place the second implementation in context and to compare the first implementation with the second implementation.

The purpose of a hybrid NoSQL-relational environment project assignment is to integrate RDBMS with NoSQL as depicted in figure 1. A hybrid NoSQL-relational environment allows a RDBMS and a NoSQL data store to exist side-by-side. The RDBMS allows for the structured storage and extraction of information, while the NoSQL data store allows for the querying of data on a needs basis – when a question comes up that cannot be answered using the RDBMS.

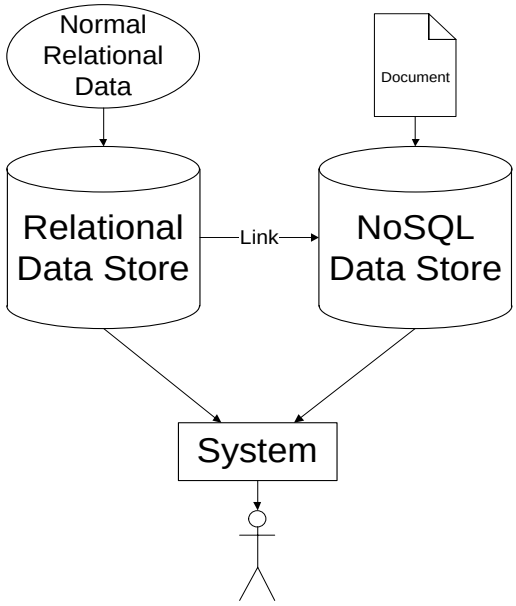

Figure 1. Relational-NoSQL Hybrid Scenario [1].

To facilitate the understanding of the link in figure 1, a typical document store example is included in figure 2.

```
[
  [
    "id:440a4e82-7c83-4288-9616-79636e4a108a",
    "file:78 1c af 76 ff e0 bf e3 7d f6 eb 2a 3b d0 40 af cd aa 39 5c
39 eb 3b 5c 58 43 b3 3b 5c 06 ",
    "manual"
  ],
  [
    "id:a980f9c0-2d48-4833-9a1f-d0284b549272",
    "file:f7 39 0e d9 3e 04 25 40 77 06 3e bb de fd 05 fa b9 6d 1d
89 c6 cb 0e db 48 2a e9 dc 7e 5a ",
    "technical"
  ],
  [ "id:93f9efae-2e2b-46aa-a8fc-ab32e637ba71", null, null ]
]
```

Figure 2. A typical document store example.

In figure 2, the "id" is used as a reference point or foreign key which is stored in the relational database, to gain access to the specific document. The "file" in this example is the hexa or binary format of a file uploaded to the database. Table 1 shows the "id" in the product table that could be used to retrieve the data from the document store.

Table 1. Relational example from a typical document store example.

product_id	name	price	document_id
PROD_1	Test Product 1	R 50.00	a980f9c0-2d48-4833-9a1f-d0284b549272
PROD_2	Test Product 2	R 150.00	id:440a4e82-7c83-4288-9616-79636e4a108a
PROD_3	Test Product 2	R 200.00	null

An example of a project assignment given to students to enhance their understanding of working with a hybrid NoSQL-relational environment – in a practical way:

> Use a NoSQL document data store to store the manuals, brochures and/or technical documentation in support of items sold in an online store. The database of item-entities may be expanded to include more related entities and will function like the relational database used by a typical e-commerce site, but in the items table a reference should be made to the documentation available in a NoSQL data store.
>
> Students may use a relational DBMS to develop a conventional database supporting a typical e-commerce site, along with a NoSQL component supporting unstructured data as suggested in the example above.

The project assignment rubric students received included two obvious items, namely:

- documentation, and
- presentation.

The items specifically pertaining to the functionality of the project assignment, included:

- physical design that focused on the proper functioning of the RDBMS with entities (tables and attributes) with their relationships, the use of procedures, functions and triggers.
- Application with the emphasis on the integration of Oracle and MongoDB, and
- The technical aspects were included to determine whether students were prepared for their presentation. Were all the necessities such as the DBMS, software used and infrastructure preloaded and in place, or did they encounter problems?

Seven groups were formed and they managed well in performing the task – with the group receiving the lowest mark getting 60% and the highest marks in the nineties. Five of the groups were fairly large (ten to twelve members) and two groups smaller with eight and four members respectively. Due to the large groups, the students divided themselves into smaller groups of 3-4 members each and each small group were tasked to research and solve a specific aspect of the project problem. Using peer evaluation students evaluated themselves and their peers based on the contributions made by each member.

Although the project assignment ended well for both the students and the lecturer, it was felt that students should be able to make sense of a hybrid NoSQL-relational environment – on their own. The groups were also felt to be too big, which may lead to a situation where students only focus on part of the problem. The first implementation lead the lecturer to make adjustments to the project assignment for implementation during the second implementation.

During the first implementation students received a case study which guided them in the project about what to do. They had to research the purposes of NoSQL and learn how to integrate this with a relational database specific to the project. During the second implementation students were given no case study. They were given aspects to investigate, such as NoSQL technology, data models and a webcrawler. In this manner they had to form their own understanding of what was required by looking at each of these aspects' functions, purposes and usages.

4.2 A second implementation

To allow project assignment groups to make sense of the assignment on their own – without the guidance of the lecturer – an "open assignment" was given and not as a conventional project assignment. In a conventional assignment students expect direct instructions to perform. In this case, the students received project assignment outcomes. In addition to this, they also did not get a project assignment rubric to guide them. An example of a project assignment description that only states outcomes:

1. Understand the use (goal and purpose) of a NoSQL database (example mongoDB).
2. Understand the use (goal and purpose) of a Relational database (example Oracle).
3. Understand the purpose of a web crawler and implement one.
4. Understand Business Intelligence, how to do data analysis and the value of a dashboard.
5. Integrate the systems to support one another.

The students received the project assignment outcomes eight weeks before their presentation date. They were requested to work in groups of six students, which most did. Of the seventeen groups that presented, three had five members, one three members and one individual who was working on a departmental assignment with some similarities, requested to work on his own. Again, students were requested to evaluate themselves and their peers based on the contributions made by each member.

The project assignment rubric used by the evaluation panel, included two obvious items, namely:

- documentation, and
- presentation.

The items specifically pertaining to the functionality of the project assignment, included:

- web crawler,
- noSQL database,
- converter or bridge to process the data from NoSQL's unstructured format to the structured format of a relational environment,
- relational database, and
- dashboard or some interface that enables a user to access the data.

To the evaluating panel, it was important that each component was functional (including that the link to the data had to be working), and met its objective. The expectation of the lecturer was that the depicted end product would realise (see figure 3). The dashed lines make provision for other routes to a similar end result.

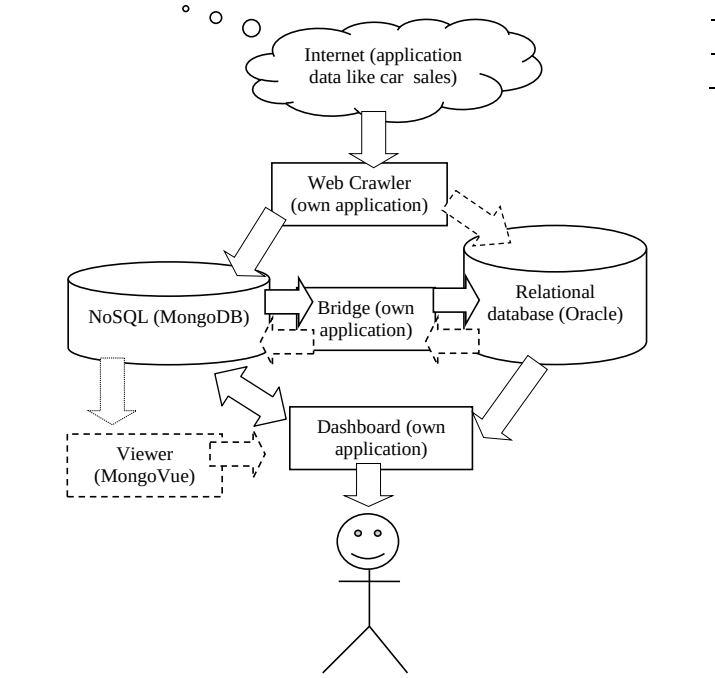

Figure 3. Project assignment application scenario.

5. STUDENT INTERPRETATIONS

The majority of the project assignment groups did achieve the hoped for end product, but some ended up with a different, illogical version. A breakdown of interpretations is shown in table 2.

To make sense of how students implemented their solutions, the researchers depicted the most preferred solution. The next step was to categorise the project assignment groups' solutions according to the outcomes features included, with each category also depicted. Most of the project assignment groups did manage to come up with a logical solution. The groups that came up with the solution depicted in figure 4, numbered 5 (unfortunately only one group attempted to allow an interface between NoSQL and the dashboard). Two more did not create a dashboard to view data, but created a conventional system to combine all features, of which the viewing of data was attempted. One group used MS Excel (instead of an application developed in a language like C#). The solutions of the eight groups mentioned above is considered a logical solution which is depicted in figure 4. It is clear that all aspects of the hybrid NoSQL-relational environment is necessary and is used in a unique way.

Table 2. Interpretations per group (excluding the individual student)

Outcome feature	Groups	Comments
web crawler	16	All groups.
noSQL database	14	
bridge	5	In addition to the groups mentioned, two groups created an application that combined all the features. One group created a manual bridge (using MS excel).
relational database	14	
dashboard	11	

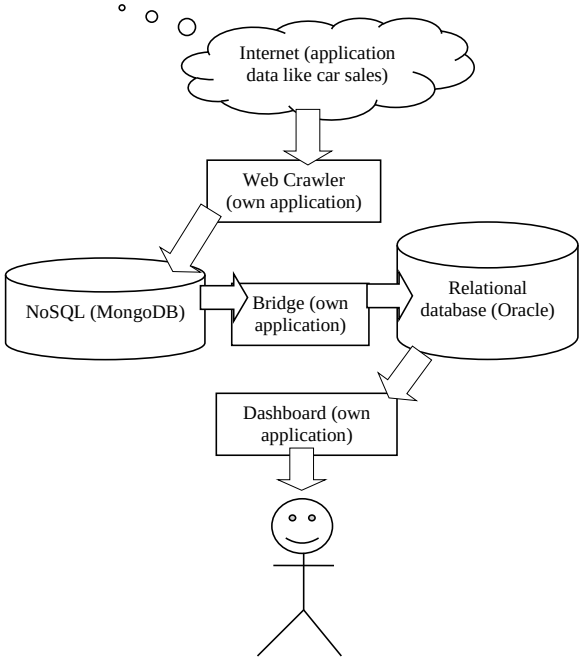

Figure 4. Logical implementation of project assignment.

Only one of these groups attempted to allow the user access to the full data source through NoSQL – on the dashboard. The group knew that feature needs to be included, but did not manage to implement the feature well. This feature is important, since it allows users to access data hidden at the point of development, although the user will have to develop a set of skills to access data that has not been made available through the dashboard. This access may be made easier to users through the use of a tool like MongoVue.

The other eight project assignment groups either struggled to make sense of the project assignment or knew what needed to be done, but did not manage to finish all the features – mostly because of time constraints or struggling to make software like MongoDB, which was new to them, work. Their implementations are depicted in figure 5, 6 and 7.

Two groups implemented a web crawler, NoSQL and the relational environment. They did not create a dashboard to access the data, but made use of MongoVue to access the NoSQL data. Their attempt is depicted in figure 5.

The problem with the implementation represented in figure 4, is that the RDBMS data has no purpose. Data is stored, but not utilised in any way to provide information to the user. It allows for an unproductive environment where the vast NoSQL data source needs to be searched to provide data that can easily be stored by a RDBMS.

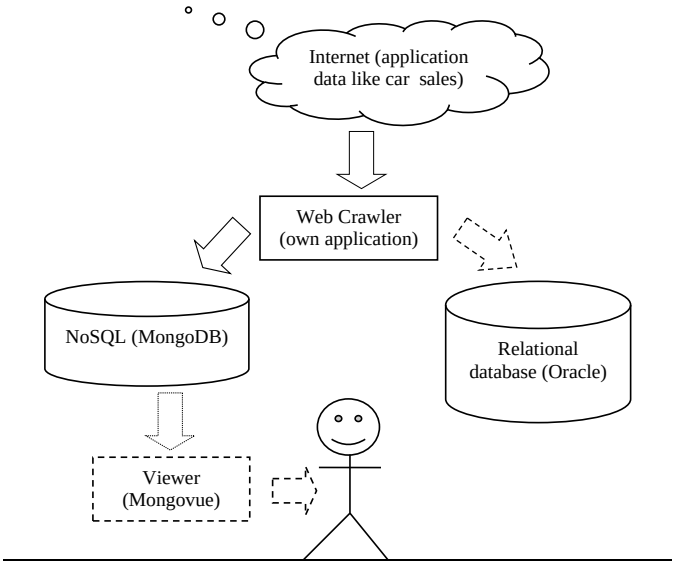

Figure 5. Implementation of project assignment without a bridge between NoSQL and the RDBMS and replacing the dashboard with a viewer.

Two groups implemented a web crawler, NoSQL, the relational environment and a dashboard, but no link between the NoSQL and relational data sources. Their attempt is depicted in figure 5.

The problem with the implementation represented in figure 6, is that the NoSQL data has no purpose. It is stored, but not utilised in any way to provide information to the user. It allows for a static environment where the information stored in the RDBMS is the only data that the user will be able to query.

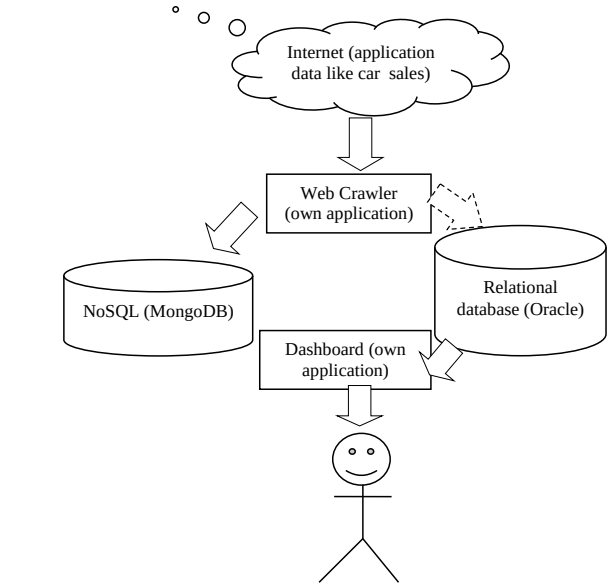

Figure 6. Implementation of project assignment without a bridge between NoSQL and the RDBMS.

Two groups implemented a web crawler, NoSQL and the relational environment, but without a dashboard and with no link between the NoSQL and relational data sources. Their attempt is depicted in figure 7.

The problem with the implementation represented in figure 7, is that in the case of the NoSQL data, as well as the information stored in the RDBMS means nothing to the user since no interface exists. These groups realised that their final product was incomplete and of no use to the user.

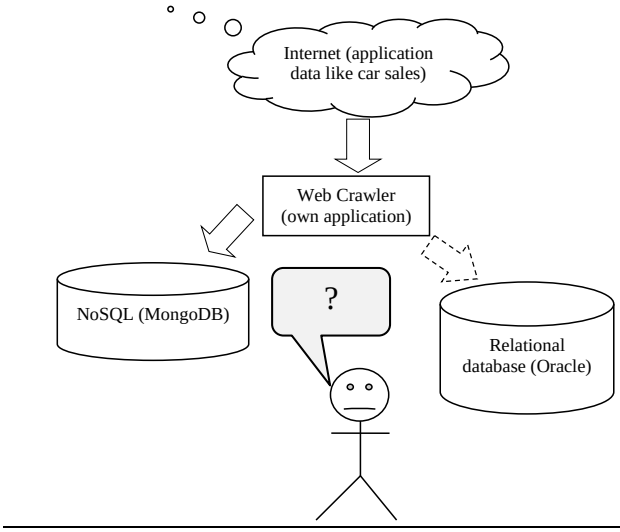

Figure 7. Implementation of project assignment without a bridge between NoSQL and the RDBMS and without a dashboard.

Of the remaining two groups one group implemented a web crawler, NoSQL and a dashboard, but the relational environment was not implemented and therefore no link between the NoSQL

and relational data sources was implemented. Their attempt is depicted in figure 8.

The last group implemented a web crawler and NoSQL. They omitted the dashboard and the relational environment was not implemented and therefore no link between the NoSQL and relational data sources was implemented. The depiction of this group is similar to that of the previous group, except that they did not attempt to create a dashboard.

The problem with the implementation represented in figure 8, is that no attempt was made to provide the user with information. These groups realised that their final product was incomplete and of no use to the user.

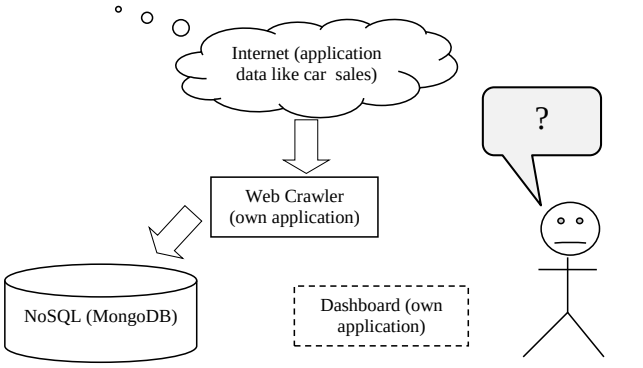

Figure 8. Implementation of project assignment without the relational database and a bridge between NoSQL and the RDBMS. The dashboard cannot display information.

6. CONCLUSION

After suggesting an amendment to a typical database systems module offered at most tertiary institutions, namely including NoSQL in the curriculum, the lecturer implemented the amended contents and included a project assignment to facilitate students' understanding of the new concepts.

Two project assignment scenarios were suggested, namely a NoSQL only scenario and a hybrid NoSQL-relational scenario. Because of time constraints, the lecturer could only implement one and chose the hybrid NoSQL-relational scenario. This scenario allowed students to build on their existing knowledge of RDBMSs, while at the same time making provision for exploring the new NoSQL technology. The NoSQL only scenario will be used for more mature students – at a later stage.

Two implementations are discussed, the first during 2013 and the second during 2014. Although the theory offered were not amended, the first implementation regarding the project assignment was a typical one where the lecturer tells the students what is expected of them regarding the assignment. The project assignment was accompanied by a rubric, an effective tool to guide students.

Although the project assignment went well, upon reflection the lecturer felt that students should be able to make sense of a hybrid NoSQL-relational environment – without help from a lecturer. The groups of ten to twelve students were also felt to be too big, and it was decided that the size should be halved.

To allow project assignment groups to make sense of the assignment on their own, the students received only project assignment outcomes. They also did not get a project assignment rubric to guide them.

In 2013 seven groups were formed and all of them managed to do the project assignment well. In 2014 seventeen groups were formed of which sixteen were used for the purpose of this paper. Only half of them managed to deliver a proper working, usable end-product. The other half of the groups managed parts of the solution, but had loose ends and developed components that made no logical sense. During their presentation sessions these groups did agree that they did not put in enough time, or procrastinated, or had some problems among group members.

Presentation sessions were structured to force project assignment groups to attend the presentations of their peers. This allowed most under performing groups to have an aha-moment regarding their incomplete or illogical solution. All groups agreed that they explored a new and very exciting world.

Upon reflection on the second implementation, it is felt that the group size should stay the same. Students should be able to make sense of the assignment on the own, but they should receive a rubric as additional guidance. More time may also facilitate an improved end product on average since most groups indicated that limited time was a problem.

In future, it may be valuable to contact students who finished their course and started a career to determine whether any of them are using the knowledge gained from the amended module. Possibly some surprising new information may come to the fore – where young employees are utilising this new knowledge in related environments and applications.

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Big Data and NoSQL Databases: New Opportunities for Database Systems Curricula

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ABSTRACT

For the last 40 years the database environment in many organisations has been largely based on relational database systems. For this reason, the database systems curriculum has been largely based the relational database model. In the last 15 years or so, other types of database systems such as object-oriented, object-relational and XML database systems have emerged, and have been incorporated into the database systems curriculum. More recently applications that generate big data have arrived on the scene, and businesses have quickly realised the new database technologies are needed for the storage and processing of big data. Recently, academic literature on incorporating the study of big data technologies into database curriculum has started to emerge. These authors argue for the need to incorporate NoSQL database systems, New SQL database systems, and the MapReduce computational framework, into the database systems curriculum. The scope of this paper is to give a brief overview of technologies for big data and report on the effective inclusion of NoSQL databases into a third year undergraduate course on database systems.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education- *computer science education, curriculum*.

General Terms

Algorithms, Languages.

Keywords

Big Data, SQL, NoSQL, New SQL, Apache Hadoop, Google MapReduce, MongoDB, Neo4j, database systems curriculum.

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1. INTRODUCTION

The relational database model, first used in the early 1970s, has dominated the database systems landscape for more than 40 years. More recently, in the last 15 years, applications that use semi-structured and unstructured data have become a necessity in (business) organisations. A common type of data which is semi-structured or unstructured is big data. Big data is defined as data with big volume, big velocity and big variety [6], [10]. Big data may be structured, semi-structured or unstructured. The web is a primary source of big data. Examples of web-generated big data are: click stream data, data for e-commerce purchasing histories (used by recommender systems), social media and social networks data (e.g. Facebook, Twitter, LinkedIn, blogs, YouTube) [8]. Other sources of big data include mobile devices (e.g. smart phones) and stock exchanges where stocks are traded continuously 24/7. Three major technologies that have emerged as solutions for the storage and processing of big data are NoSQL database systems [7], [10], [14], New SQL database systems [15], and MapReduce computation [2], [4], [15]. The traditional database systems curriculum is, to a large extent, based on the relational database model [1]. Recently, academic literature on incorporating the study of big data technologies into database curriculum has started to emerge (e.g. [13], [14]). These authors argue for the need to incorporate NoSQL database systems, New SQL database systems, and the MapReduce computational framework, into the database systems curriculum. The scope of this paper is to give a brief overview of technologies for big data, and report on the effective inclusion of NoSQL databases into a third year undergraduate course on database systems. The rest of the paper is organised as follows: Section 2 provides an overview of the database systems landscape and curriculum. Section 3 provides a brief overview of NoSQL databases with a special focus on MongoDB (a document database) [11] and Neo4j (a graph database) [9], [12]. Section 4 provides a discussion of how the MongoDB and Neo4j databases have been incorporated into a third year course on database systems. Section 5 concludes the paper.

2. DATABASE SYSTEMS LANDSCAPE AND CURRICULA

This section provides and overview of relational database systems, database systems for big data, and database systems curricula.

2.1 Relational database systems

A relational database is based on a schema [3]. The schema specifies the attributes (fields), primary key and foreign key(s) for each relation in the database. All insert and update operations are checked to ensure that they do not violate primary key and foreign key constraints. Additionally, in a multi-user environment, all database operations are implemented as transactions. ACID (atomicity, consistency, isolation, durability) guarantees are enforced for all transactions. Atomicity ensures that the entire transaction must be completed otherwise the transactions fails. Consistency ensures that a transaction moves the database from one valid state to another valid state. Isolation ensures that transactions do not interfere with each other's operations. Durability ensures that once a transaction has been committed, it will remain committed. Given the foregoing observations, one can see that the RDBMS is an ideal solution for transaction processing of business data.

2.2 Weaknesses of the relational database model

In recent times businesses have started collecting data which is semi-structured or unstructured [10]. This is in contrast to traditional business data which typically consists of numeric values and short strings of text. Semi-structured and unstructured data consists of document files, pictures, blog posts, video clips, audio files, etc. Additionally, it is not always easy to establish once and for all, what attributes to store for semi-structured and unstructured data. Relational database systems were not primarily designed for this type of data [10]. One of the major weaknesses of the relational database model is that, due to normalization, information is most commonly obtained from the database through performing a join (intensive computation) of two or more tables [3]. A second major weakness is due to semantic overloading. This means that a single construct, the relation, is used for representing data and data relationships. There is no mechanism to distinguish between relations and relationships, or between different types of relationships [3]. A third weakness is due to the fact that the relational model is a homogeneous data structure. Horizontal homogeneity means that each tuple (table row) is composed of the same attributes. Vertical homogeneity means that the values of an attribute come from same domain. Additionally, the intersection of a row and a column must be atomic, that is, it cannot store an object that can be decomposed into its components for design purposes [3]. A major extension of the relational model is the object-relational database system, which extends the relational model with object-oriented features (classes and objects). By doing so, it enables the storage of structured, semi-structured (e.g. XML) and unstructured data (e.g. CLOBs and BLOBs). It also reduces the need for table joins, but does not completely eliminate the need for joins [3].

2.3 Database systems for Big Data

Big data is defined as data with the following characteristics: big volume, big velocity and big variety. Big volume means that the generated data is at a scale of terabytes to petabytes [10]. Big velocity means that the data is in motion, that is, it is arriving at high speed. Big variety means that the generated data is in many forms, that is, structured, semi-structured, unstructured, text, and multimedia data. Three technology solutions that have emerged for storing and processing big data are NoSQL database systems, New SQL database systems and MapReduce computation. The MapReduce computation framework was introduced as a programming model by Google in 2004 [2], [4], [14]. MapReduce enables the implementation of highly distributed programs that run on failure-tolerant and scalable clusters of commodity machines. Examples of MapReduce implementations are: Apache Hadoop [2], Google MapReduce [4], MicroSoft Dryad.

NoSQL (Not only SQL) databases have emerged in recent times as one of the solutions for storing and processing unstructured data [7], [10], [13], [14]. NoSQL database systems are distributed non-relational databases designed for large-scale data storage and for massively parallel data processing using a large number of low cost servers in order to provide scalability, availability and fault tolerance [10]. NoSQL databases arose alongside major Internet businesses which had challenges in storing and processing huge quantities of data. Examples of these organisations are Google, Amazon, Facebook and Yahoo! Today NoSQL databases are used by organisations that collect large amounts of semi-structured and unstructured data (e.g. for analysis purposes). In general, NoSQL database systems are schema-less (i.e. do not enforce a schema), or schema-optional (i.e. may be used with or without a schema) and may or may not provide any ACID guarantees. New SQL database management systems aim to have the same level of scalability and availability as NoSQL database management systems but still maintain the ACID properties, support the relational data model and SQL as the primary mechanism for application interaction, and provide real-time OLTP and conventional OLAP in Big Data environments [14], [15].

2.4 Database systems curricula

The modern database systems curricula typically include a discussion of relational databases, object-oriented databases, object-relational databases, Geo-spatial databases, and XML databases. The Joint Task Force on Computing Curricula, supported by the ACM and IEEE provides guidelines on Computing curricula. In their December 2013 report [1], it is recommended that approaches for managing large volumes of data (e.g., NoSQL database systems and the use of MapReduce), should be included in the database systems curriculum ([1] pp. 117). It is also recommended that MapReduce should be included in the curricula on parallel computing ([1] pp.342-369). There is however no mention of New SQL.

3. NoSQL DATABASES

NoSQL databases systems are briefly reviewed in this section. The MongoDB document database and Neo4j graph database are discussed in a bit more detail as the teaching recommendations given in this paper are based on experiences with these two database systems.

3.1 Categories of NoSQL databases

There are currently four categories of NoSQL databases namely: key-value stores, document stores, wide-column stores, and graph databases [10]. Key-value stores store data entries as key-value pairs where the key uniquely identifies the value (data item). The value may be a word, number or complex structure with unique semantics. Document stores (databases) are designed to store documents. The documents are encoded in a standard data exchange format e.g. XML, JSON (JavaScript Object Notation), BSON (Binary JSON). The data is stored in key-value pair style but the value column is un-structured data (document). Two example of document stores are MongoDB and Apache's CouchDB. Wide-column stores use a distributed, column-oriented data structure which accommodates multiple values per key. These databases use Google's Bigtable structure and file systems (GFS) and MapReduce parallel processing. Graph databases use graphs of interconnected key-value pairings. A graph is represented as an object-oriented network of nodes (objects), edges (node relationships), and properties (object attributes expressed as key-value pairings). Examples of graph databases are Neo4j, InfoGrid and AllegroGraph [10].

3.2 MongoDB document database

MongoDB is a document-oriented database which provides high performance, high availability and high scalability [11]. This database works on the concepts of collections and documents. A MongoDB database is a physical container for collections, has its own set of files on the file system, and a single server has multiple databases. A MongoDB document is a set of key-value pairs in JSON format as depicted in Figure 1. A MongoDB collection is a group of MongoDB documents. The database does not enforce a schema. This means that documents within a collection can have different fields and structure. However, typically all documents in a collection are of similar or related purpose. There are two approaches to modeling the documents in a MongoDB collection. The first approach is called the embedded document model. The second approach is called the normalised data model. With the embedded data model, related data is embedded in a single structure or document. These schema are generally known as "denormalized" models, and take advantage of MongoDB's rich documents. For the normalized data model document references are used to record relationships between documents, but the 'joining' of documents must be done in the application's code.

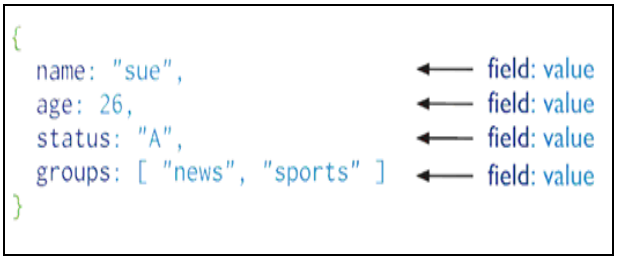

Figure 1: An example of a MongoDB document (adopted from [11])

The database system uses a client-server model with a server process called *mongod* and a client process called *mongo*. The server process (*mongod*) accepts connections from client (*mongo*) processes and database applications, e.g. Java applications. The client process provides a shell (the *mongo shell*) which is based on JavaScript. Additionally, MongoDB provides client drivers for many languages such as C++, C#, Java, .NET, PHP, and Python. MongoDB does not support multi-document ACID transactions. However, MongoDB provides atomic operations on a single document.

3.3 Neo4j graph database

Neo4j is a graph database which uses the graph model [12]. A graph model is a labeled and directed multigraph. A labeled graph has a label for each edge (type for edge). A directed graph uses edges with fixed direction. A multigraph allows multiple edges between two nodes. In a property graph model data is modeled using three basic building blocks, namely: nodes, relationships and properties. A node is also known as a vertex. A relationship, also known as an edge, has a direction and a type, is labeled and directed. Properties, also known as attributes, are specified for nodes and relationships. A property graph model is implemented as an object-oriented network of nodes (objects), edges (node relationships), and properties (object attributes expressed as *key-value* pairings). Neo4j uses the property graph model. Additionally, labels are used to associate nodes as a 'group'. As an example, in a graph database for a social network, the label 'Person' may be attached to each node that represents a person. When this is done, queries can be specified for 'Person' nodes. Figure 2 provides an example of a very simple Neo4j database for a social network.

A query language, Cypher, is provided for accessing the Neo4j database. Cypher is a special-purpose language for working with graph data. It is declarative (like SQL) and uses familiar SQL-like clauses. It uses patterns to describe graph data. Additionally, according to the Neo4j documentation, true ACID transactions are fully supported.

The Neo4j graph database uses a client-server model. Two types of client software are provided: a shell client and a web-based client. There are three basic ways to using a Neo4j database:

(1) Neo4j server process and shell client or web-based client. In this approach, Cypher queries are typed (issued to the server) using the client.

(2) Neo4j server process and REST (REpresentational State Transfer) API from an application e.g. Java application. The REST API uses HTTP and JSON, so that it can be used from many languages and platforms. REST facilitates a simple and fast access to databases through HTTP. The HTTP methods POST, GET, PUT, DELETE can be used to interact with the database to perform CRUD operations. POST is used for the CREATE operation, GET is used for the READ operation, PUT is used for the UPDATE operation, and DELETE is used for the DELETE operation.

(3) Neo4j embedded in Java applications: With this approach, Neo4j is embedded in a Java application by including the Neo4j library jars in the application project. The library is available for download from the Neo4j website [12].

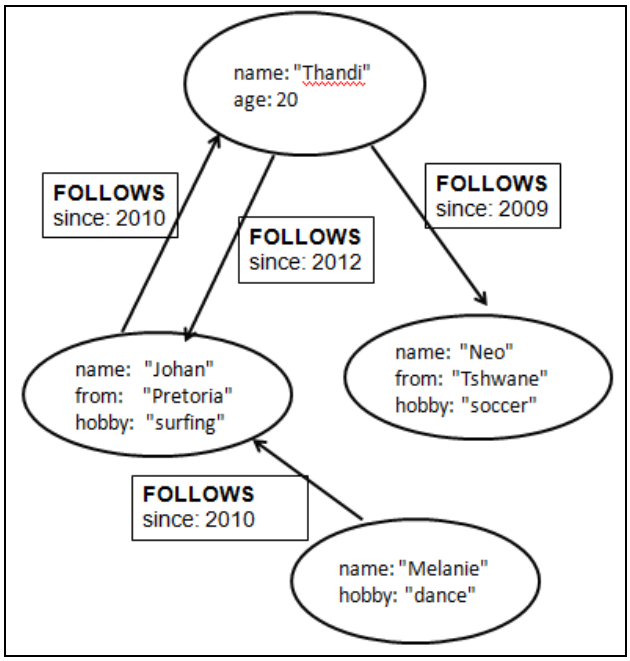

Figure 2: A simple graph database for social network data

4. RECOMMENDATIONS

Given the above discussion, it makes sense for database systems curricula to include NoSQL database systems. A number of researchers (e.g. [13] and [14]) have written papers which give some good recommendations on the inclusion of databases for Big Data into the computing curriculum. The purpose of this paper is to provide some guidelines on how to incorporate NoSQL databases into the undergraduate database systems curriculum. This section provides guidelines (based on experience) on how document databases, and specifically MongoDB, and graph databases, specifically Neo4j, can be easily and effectively incorporated into a third year the undergraduate database systems course in Computer Science.

4.1 Learning objectives for NoSQL database systems

Silva et. al [14] have suggested the following learning outcomes, for students, when integrating big data into computing curricula: (1) recognise the key properties, strengths and limitations of each type of Big Database Management System (BDMS), (2) build applications using specific instances of each type of BDMS, (3) understand when to use each type of BDMS. The author (of this paper) has presented a third year course on database systems with NoSQL database systems as one of the components of the course. The other components of this course are: object, object-relational, geospatial, and XML database systems. For document databases, MongoDB is used to teach document database concepts because it enjoys widespread usage in big data database environments. For graph databases, Neo4j is used. The learning objectives for the document databases and graph databases components are given in Table 1.

Table 1: Learning objectives for Big data and NoSQL database systems

Learning objectives	**Topics covered**	
1. Discuss the basic concepts for Big Data	Definition of big data, sources of big data, MapReduce, NoSQL, New SQL, when to use relational, NoSQL and New SQL databases.	
	for MongDB	**for Neo4j**
2. Discuss the basic organisation and components of the database system	document, collection, database, data models, data types, client (mongo) and server (mongod) processes	graph data model, nodes, relationships, node properties, relationship properties, labels, client (web-based) and server processes
3. Discuss the database operations	CRUD operations, specification of relational operators, projection, sorting, indexing, aggregation queries and MapReduce functions	Cypher query language and CRUD operations, path queries, aggregations, functions, graph algorithms (shortest path, clustering coefficient)
4. Discuss writing code (client-side functions and Java applications) to access the database	implementation of mongo client functions in JavaScript, implementation of Java applications which access the database.	**Not covered:** implementation of Java applications which access the database using the REST API, and using a Java library.

4.2 Timeframes for the learning objectives

All the students who register for the database course have a high level of competence in Java and JavaScript programming, and are very familiar with JSON objects. Additionally, they have already attended at least one course on relational database systems so that they know database systems concepts and terminology such as Entities and relationships, ACID, CRUD, aggregation, sorting, and indexing. This makes it very easy for them to follow the

discussion of the topics listed in Table 1. The topics for the discussion of the basic concepts for big data are covered in two one-hour theory lectures. The topics for MongoDB are covered in three one-hour theory lectures, one three-hour tutorial (practical) session and one three-hour practical session. Due to time constraints, only the topics for learning objectives 2 and 3 in Table 1 were covered for Neo4j. These topics were covered in three one-hour theory lectures one three-hour tutorial (practical) session and one three-hour practical session. The author estimates that it would take three one-hour theory lectures, one three-hour tutorial (practical) session and one three-hour practical session to cover the topics for learning objective 4 for Neo4j. So, if students have the necessary background, the topics listed in Table 1 can effectively be covered in eight one-hour theory lectures, three three-hour tutorials and three three-hour practical sessions. One major challenge is that there is no textbook for the NoSQL component of the course. Students are required to read journal papers and the user manuals for the databases. The user manuals are very long documents (more than 500 pages) so the lecturer (the author) selects specific sections for them to read and work through (tutorial style). It is recommended that the theory lectures, tutorials and practical sessions should be spread over a period of at least four weeks in order to give students a reasonable amount of time to absorb the material.

4.3 Resources for teaching NoSQL database systems

The reader will recall that NoSQL database systems are *distributed* non-relational databases designed for large-scale data storage and *for massively parallel data processing using a large number of low cost servers* in order to provide scalability, availability and fault tolerance. So, five questions that come to mind are:

(1) *Can a university department afford the computing equipment to support massive parallelism?*

(2) Can a university department afford the technical expertise to set up the distributed computing environment?

(3) Can a university department afford the software for NoSQL database systems?

(4) Can students cope with this level of complexity? (5) Where can one obtain the big data for the practical work?

The good news is that NoSQL databases and MapReduce software e.g. MongoDB, Neo4j and Apache Hadoop, are available as Free/libre/open source software (FLOSS). FLOSS is software that is licensed to grant users the right to use, copy, study, change and improve its design through the availability of its source code. 'Free' refers to the freedom to copy and re-use the software, rather than to the price of the software [5]. For teaching purpose, community editions are available to download and use for free. The software can be installed for single-node (single machine) usage, and this is easy to do, either on Linux or a Microsoft Windows platform. With a single-node installation, the topics listed in Table 1 can effectively be taught to students. In addition to the use of single-node step-ups, academic institutions have started creating teaching resources for big data technologies. Examples of this are discussed by Silva et. al [14] who report on virtual machine software and other resources for teaching MapReduce computation, NoSQL and New SQL database systems. Their virtual machine software is available on request. The main motivation for using a virtual machine is that configuring a physical set-up for "*a distributed system for massively parallel data processing using a large number of servers",* (e.g. Apache Hadoop) is technically very challenging [14]. In terms of data for the practical work, it is not necessary to use huge volumes of data for the practical work in order to achieve the learning objectives of Table 1. The user manuals for MongoDB and Neo4j provide URLs for sample data that can be used for tutorials and practical assignments. At the time of writing, one URL example is http://media.mongodb.org/zips.json3 for MongoDB.

5. CONCLUSIONS

It has been reported in the literature that the current database environment in organisations includes the use of big data technologies, namely: MapReduce, NoSQL and New SQL. This paper has presented a brief overview of current database systems curriculum, technologies for big data, the challenges, and presented an effective approach for the inclusion of NoSQL database systems into a third year undergraduate course on database systems.

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Experience in the Formulation of Memoranda for an Automarker of Simple Programming Tasks

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ABSTRACT

We have gained experience over the past ten years while teaching an introductory programming module where the assignments are automatically assessed. Our experience of using automatic assessment improved our skills in setting clearer assignments of a higher quality, which are easier to assess. We use an example to describe how we set an assignment. This example assignment and its memorandum were the starting point for the design of a new memo format for our automarker. The strategies used for setting the assignment were developed for setting assignments suitable for automatic assessment. We explain how these strategies can be used for setting an assignment and formulating the instructions for its manual assessment. This is a guideline for creating quality assignments of this kind.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and information Science Education; K.3.1 [**Computers and Education**]: Computer Use in Education.

General Terms

Human Factors

Keywords

Programming assignment, assessment, automatic assessment

1. INTRODUCTION

The Programming assignments have been assessed automatically for almost the same length of time as programming has been taught. Automated assessment is employed in many programming courses at tertiary education institutions [6, 10, 12].

In February 2016 we will celebrate the tenth anniversary of our own system, called Fitchfork, which we use for the automatic assessment of programming tasks. When assessing a program, Fitchfork compares the output produced by a student's program with a specified expected result.

Each program submitted is executed several times, each time with different test data as stipulated in a memorandum.

Regular expressions are used for the specification of the expected output for each test case. Students submit their programs by uploading via a web interface and receive their feedback on the same interface.

The quality of the assessment and feedback given as a result of the assessment depend on the rubric used for the assessment.
The formulation of assessment instructions is an art, whether the assignment is intended to be assessed using an automarker such as Fitchfork or intended to be assessed manually. In this paper we present a tutorial on how to create quality programming assignments. To this end, we describe the design of an assignment and the specification of its assessment rubric. The rubric is aimed at automatic assessment but could easily be formulated for manual assessment.

Section 2 describes a sample assignment as a means of illustrating the different aspects of a rubric for assessment. The formulation of rubrics and memoranda is closely linked to the principles of software testing. In Section 3 we illustrate how testing theory informs the way we design a test suite for a memo. Section 4 emphasises feedback as an important aspect of formative assessment and indicates how it should be incorporated in a memorandum for automatic assessment. An often neglected aspect of assessment is balancing the difficulty level of questions with the allocation of marks to ensure fairness. In Section 5 we describe our rule of thumb for doing this. Table 2 is the outcome of a typical balancing act which we usually apply before setting a memo for automatic assessment. Section 6 gives an example of how this is translated into assessment instructions for the manual evaluation of the assignment described in Section 2.

2. THE ASSIGNMENT

Assessment is intended to measure the students' competence with specific programming concepts. When one has to set an assignment to achieve this goal, one has to identify the learning outcomes, formulate the tasks aimed at testing the learning outcomes, select a theme and design an assignment based on these elements.

Our sample assignment is designed to provide experience in the manipulation of C-String type arrays – null terminated

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character arrays. Typically one would require the students to be able to use an appropriate variable to hold a C-String, to initialise the variable with a value which is read from the keyboard, and to apply some of the functions listed in Table 1. The assignment should also reinforce the definition and use of user-defined functions.

Programming the word game called Pig Latin requires the student to use the above-mentioned skills, making it a suitable theme for the assignment.

3. TESTING

It is important for students to know how to test the functional correctness of their programs. To support this, Basu et al. [3] provide test suites and require their students to prove their understanding of the purpose of a test case before allowing them to apply it. Students with a better understanding of testing are better equipped to accept the results from an automarker [9]. For this reason, we teach our students techniques for designing test cases. We apply these techniques when designing our test suites for assessing a program.

Table 1. Functions identified as required learning outcomes

Function	Description
`bool isalpha(char)`	Returns **true** if the argument is a letter of the alphabet and **false** otherwise.
`bool isupper(char)`	Returns **true** if the argument is an uppercase letter and **false** otherwise.
`bool islower(char)`	Returns **true** if the argument is a lowercase letter and **false** otherwise.
`char toupper(char)`	Returns the uppercase equivalent of its argument.
`char tolower(char)`	Returns the lowercase equivalent of its argument.
`int strlen(char[])`	Returns the number of characters in its argument.
`void strcat(char[], char[])`	Appends the second argument to the first argument.

Assignment

Pig Latin is a constructed language game. English words are altered according to a set of rules to conceal their meaning. The reference to Latin is a deliberate misnomer, as it is used only for its English connotations as a foreign-sounding language. The rules for changing standard English into Pig Latin are as follows:

- For words that begin with a consonant, the initial consonant or consonant cluster is moved to the end of the word, and "ay" is added, as in the following examples:
  - "happy" → "appyhay"
  - "duck" → "uckday"
  - "glove" → "oveglay"
- For words that begin with a vowel, "way" is added at the end of the word, as in the following examples:
  - "egg" → "eggway"
  - "inbox" → "inboxway"
  - "eight" → "eightway"

The following example is a test run of the program:

```
Enter English word: happy
The Pig Latin for happy is appyhay
```

Specifications

- Write a function called isVowel. It should have one argument of type char. It should return true if the argument is a vowel and false otherwise.
- Write a function with the following prototype

  ```
  void toPigLatin(const char[], char[])
  ```

  The first parameter is the input. After calling the function, the second parameter should contain the Pig Latin of the given word.
- Write a program that uses the above functions. It should prompt the user for a word and convert the given word into Pig Latin. It should accept a word in mixed case and output it in Pig Latin in lower case only.
- The program should produce an error message if the user input is not a character string which contains only alphabetical characters.

We usually include a sample test run of the required program when specifying an assignment. This sample uses limited test cases. We expect the students to design and apply their own test suites before submitting their assignments. If their own test suite does not cater for certain cases which have been included in the test suite used in our memorandum, the feedback when failing such cases should guide the students to identify the missing cases in their own test suites.

The test cases used in the assessment have to be well thought out so that the assignment can fairly measure the competencies it is intended to measure. The quality of the assessment relies heavily on the effectiveness of the test suites applied when testing the students' programs.

Table 2 describes a test suite for our example assignment. There is no need to have test cases with words starting with more vowels, as the program is not required to behave differently in such cases.

4. FEEDBACK

Assessment is integral to the learning process. When applied to assessing the students' progress it is called summative assessment. When assessment is applied to support learning, it is called formative assessment. Formative assessment requires a feedback cycle [3, 14]. Feedback helps students to discover errors in their programs and to learn from their mistakes. When students are allowed multiple submissions, as can be arranged when using an automarker, they may revise their submissions to reinforce this learning [11].

The accuracy and usefulness of feedback rely on the accuracy of the test cases as well as on the way the person who assesses or sets the memorandum for an automarker formulates the feedback. The theories regarding the error messages produced by software provide useful ideas that should be used when formulating the feedback.

Table 2. Test suite for automatic assessment Functions identified as required learning outcomes

Test case	Basic	Quality	Extreme
Evaluate the input prompt			
Prompt has expected keyword	2		
Prompt ends with colon and space		1	
Evaluate the `bool isVowel(char)` function			
argument is a vowel in lowercase	3		
argument is a vowel in uppercase		1	
argument is a consonant in lowercase	3		
argument is a consonant in uppercase		1	
argument is not an alphabetical character			1
argument is the null character			1
Evaluate translation to Pig Latin			
input is a word starting with a vowel	3		
input is a word starting with a single consonant	3		
input is a word starting with a consonant cluster of two letters	3		
input is a word starting with a consonant cluster of three letters		3	
input is a word starting with a consonant cluster of seven letters			1
Evaluate conversion to lower case			
input is a word in lowercase	3		
input is a word in uppercase		2	
input is a word in lower case with the first letter in uppercase		1	
input is a word in lower case with some letters in uppercase			1
Evaluate the error message			
input is a word containing non-alphabetical characters		1	
input is an empty string			1
Total	20	10	5
Percentage of total	57.1%	28.6%	14.3%

5. BALANCE

The criteria for the effective assessment of the identified outcomes by using the selected tasks involve weighting the importance of tasks, estimating their difficulty and balancing the marks allocated for a fair assessment of the specific outcomes in question.

This is not a trivial task. A well-founded framework should be used. One of the most familiar educational frameworks of this kind is the *Taxonomy of Educational Objectives* commonly referred to as Bloom's taxonomy [**Error! Reference source not found.**]. Anderson [**Error! Reference source not found.**] explains that such a taxonomy is an important instrument for the preparation of assessment tasks. Ideally each examination, test and task should be evaluated and balanced by using the now widely accepted revised Taxonomy for Learning, Teaching, and Assessing by Anderson et al. [**Error! Reference source not found.**] or the equally applicable and more modern SOLO taxonomy [**Error! Reference source not found.**].

Johnson and Fuller [**Error! Reference source not found.**] acknowledge its use as a way of ensuring that assessment strikes the right balance between the rote learning of content and high-level skills such as synthesis and evaluation, whereas Scott

[**Error! Reference source not found.**] blames an imbalance in the levels of Bloom's taxonomy in tests and assignments for the bimodal distribution of frequencies versus test scores often observed in computer science tests.

Instead of using a comprehensive framework such as the above-mentioned frameworks, we find it adequate to evaluate the difficulty level tested in each test case, using the following three levels:

Basic Students who has a basic understanding and application of the specific learning criteria for the task, should pass the test.

Quality Students who apply general quality requirements without an explicit instruction to do so, should pass the test.

Extreme Students who have a deeper understanding and implement robust programs capable of dealing elegantly with extreme tests should pass the test.

Even with the best intentions, such classification remains highly subjective. It is depends on many factors, such as how the task was formulated, the amount of guidance the students received before being given the task, the level of assistance students received while programming their solutions and the current competency level of the students.

As a rule of thumb, at least 50% of the marks should be allocated to basic cases and not more than 15% of the marks should be allocated to extreme cases. This can be achieved by adjusting the weight assigned when passing each of the test cases. Table **Error! Reference source not found.** shows how we classified the test cases for our sample assignment in the above-mentioned levels. The values indicate the marks to be allocated when passing each of the test cases to ensure that the assessment of this assignment complies with our rule of thumb.

The rule of thumb may be adjusted. It is acceptable to strike a balance over a number of assignments instead of balancing each assignment individually.

6. MEMORANDUM

The rubric shown in Table **Error! Reference source not found.** was compiled with the intention to use it to formulate a memo for Fitchfork. When doing so, the program is executed for each test case. In forthcoming research we will apply it to guide the design of a new schema for the formulation of memos for Fitchfork. Here it is used as a guide to compile the instructions for manual assessment shown in Table **Error! Reference source not found.**.

Table 3. Instructions for manual assessment

Criterion	Mark
Prompt is clear, ends with colon and space and expects user input on the same line.	3
`bool isVowel(char)` function returns the expected result for uppercase and lowercase alphabetical characters as well is for non-alphabetical characters and the null character.	10
`void toPigLatin(const char[],char[])` function has the expected postcondition when called with a word starting with a vowel and with words with 1, 2, 3 or more consonants.	13
The output should be given in lower case if input is lower case, upper case or mixed case.	7
An error message is displayed when a word containing non-alphabetical characters or empty input is given. It should be descriptive of the error and echo the input.	2
Total	35

7. Conclusion

We have come a long way in refining the system and the methods we use for designing programming assignments so that they can assess the competencies of our students efficiently and accurately.

As a first step in addressing the deficiencies of Fitchfork [7], a decision was taken to redesign the schema for the formulation of its memoranda. This paper is the outcome of preliminary work needed to illustrate the viability of a new schema.

This article showcases an assignment. We give details of how it was developed. We describe the grounds for our decisions during its development. We designed a rubric aimed to be translated into a memo for Fitchfork. Although the design of the assignment is intended for use in our automatic assessment environment, we deem it a good strategy that could be applied if the work is assessed manually. We show how the rubric for automatic assessment can be transformed to serve as a rubric for manual assessment.

The need to gear our assignments towards automatic assessment led to the development of strategies to create assignments which are clear and assessment instructions which are fair. We share this experience in the hope that it may inspire other educators to be more conscious of how they assess. We also hope they can reap the benefits of our experience to renew their assessment in the same way as we constantly aspire to do ourselves.

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On the Future of Computer Science in South Africa: A Survey amongst Students at University

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ABSTRACT
The number of those computer science students, who intend to become academics (scientists or researchers) in their future career, is currently very low, and so is the 'popularity' of the mathematical courses in the CS curriculum. Most CS students of nowadays seem to behold the university as an industrial job training facility rather than a home of science. This situation leads to concerns about the future of academic computer *science* in a late-modern society which is ever more depending on the 'production' of scientific knowledge. This short-paper presents and interprets the results of a recent survey amongst university students in this context, and suggests that those problems may be tackled in the future by means of differently designed curricula for differently motivated students with different prospective careers.

ACM Categories and Subject Descriptors
K.0 [Computing Milieux], K.7 [The Computing Profession]: K.7.1 *Occupations*.

General Terms
Human Factors.

Keywords
Survey amongst students, future of academic computer science, differently designed curricula for differently inclined students.

1. MOTIVATIONS
"Don't blame me for the fact that competent programming, as I view it as an intellectual possibility, will be too difficult for 'the average programmer': you must not fall into the trap of rejecting a surgical technique because it is beyond the capabilities of the barber in his shop around the corner" – Edsger Dijkstra, **1975**.

"The required techniques of effective reasoning are pretty formal, but as long as programming is done by people that don't master them, the software crisis will remain with us and will be considered an incurable disease. And you know what incurable diseases do: they invite quacks and charlatans in, who in this case take the form of software engineering gurus"

– Edsger Dijkstra, **2000**.

"It is not the task of the university to offer what society asks for, but to give what society needs" – Edsger Dijkstra, **2000**.

Repeatedly I have noticed throughout the years that students in my courses respond to unexpected difficulties or challenges with resistance rather than with curiosity, for example in a recent 3rd-year course about formal semantics [14]. Similar experiences have also been made in the USA where *"students influenced by the difficult job market also question why they need to take subjects that are not directly related to what they will do when they leave college"* [11]. For most of my students nowadays the classical function of a university as a 'house of science' (or a 'republic of scholars'), in contrast to a vocational college or trade school, seems to have become irrelevant. The background of this current international trend was recently illuminated [12]. Specifically for the discipline of CS this phenomenon was predicted already more than thirty years ago: *"Some of the graduates of the recommended program will continue academic work in computer science (...), but most will seek employment upon graduation"* [2] though there was no indication in that document about how small the number "some" would be. The fact that also science itself is a proper profession –as it was explained by Max Weber to the Bavarian students in an invited lecture [13] which the students themselves had organised– seems to have been forgotten by many students of nowadays, for whom 'employment' is per-default associated with the commercial industry. Elsewhere I have already described the measurable effects of those trends with regard to the numbers of academics (scientists and teachers) and the difficulty of staff-recruiting in academic departments of CS and related disciplines [6]. Motivated by those observations and problems I have conducted a survey –see below– the main purpose of which was to determine the proportion of students who would still be willing (against the trend) to serve as the next generation of academics at university. Computing being a technical subject with highly-paid career opportunities outside academia, I have already expected beforehand that only a small number of answers would indicate any inclination towards an academic career. This local and subject-specific situation, however, might possibly differ from the situation in other faculties, such as the humanities, or from the situation in other countries in which the academic salaries might possibly look more attractive when compared against available (or non-available) options outside university.

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Within the general theme of SACLA'2015, namely: *"renewing ICT teaching and learning"*, this short-paper contributes to the following called-for **topics**:[*]

- **Renewing curricula**,
- **Renewing teaching-management**.

2. DESIGN OF THE SURVEY

Without revealing the epistemic interests 'behind' the survey, I merely asked the students to voluntarily do a small questionnaire about their future career plans; (permission by the faculty's ethics committee was obtained for this purpose). A sufficiently large cohort of students participated [5]. Copies of the questionnaire paper were handed out at almost the same time in three groups of CS students: one in study-year 2 (undergraduate curriculum), one in study-year 3 (undergraduate curriculum), and one in study-year 4 (the 'honours' curriculum in the South African academic system). Doing the same survey almost simultaneously in groups of different study-years (2, 3, 4) aimed at finding out whether the students' academic age significantly influenced their prospective professional inclination. First-year students were *ex*cluded from this survey under the presumption that very young students would still be too 'disoriented' about their future careers.

To prevent selection-bias the survey was taken in courses that are compulsory for *all* students at the local CS department, such that I would not accidentally 'filter out' the more industrially or the more scientifically oriented students by visiting an elective course. Visiting compulsory courses also ensured the needed number of answers for the sake of reliability. To avoid suggestive-question-biases which are typical for surveys with pre-formulated answer-options, the questions were asked in an 'open' style. The paper itself was structured in the following form:

- **About yourself** (please underline): I am: ♀ *female* / ♂ *male* (including the option not to underline anything),
- **In which profession** OR job OR role OR other activity do you 'see' yourself *immediately after* your degree? (please describe): .....
- **In which profession** OR job OR role OR other activity do you 'see' yourself *several years after* your degree? (please describe): .....

The purpose of the first question was to determine if the students' academic-scientific inclination (if any) had perhaps shifted from the (traditionally) male into the female domain.

For the sake of authenticity the students were given merely *five minutes time* to scribble their answers, such that they would not distort their own 'spontaneous intuition' by spending too much time with rational reflection and re-considerations of the matter during the survey.

3. DATA AND RESULTS

3.1 Raw Data

All answers were gathered at *university* –not: vocational college– in the middle of the South African academic year. Due to shortage of page-space available for this report, the details of the students' anonymous answers have been published 'online' [5], whereby I have slightly compressed longer sentences to their main nouns for the sake of brevity; (for example: a written sentence such as *"I would like to become a software engineer"* is represented in the data sheet [5] by the brief term 'software engineering'). With all the raw data thus provided, the readers of this report can critically re-interpret my findings or discover more subtle trends in the data.

3.2 Analysis and Interpretation of the Data

For the purpose of this short-paper I did not need to look into the all the details of the many possible IT-related career paths, short-term or long-term, which the students have mentioned in their answers [5]. The career paths envisaged by those students are not particularly 'visionary' or 'revolutionary'; they fit well into the usual social norms and conventions of nowadays. Thereby –no surprise– the answers given by the older students were typically somewhat more 'realistic' than the answers provided by the younger students: those were still somewhat more 'tentative' or 'colourful' in parts. Also not surprising in this field of study is the often-expressed desire to eventually leave the technical details of IT-labour behind, in order to become an administrator, manager, director, or employer at a higher level of authority: see Nagl's post-graduation career survey in Germany for comparison [8].

As far as the main problem *–can we effectively produce the next generation of academics in CS?–* of this case study is concerned, it was necessary to watch out particularly for those students who, in their answers:

- aim for the MSc or the PhD degree (even without explicitly mentioning an academic career), or
- aim specifically and explicitly for a profession as academics, lecturers or researchers, (thereby self-understandingly implying the higher degrees).

Moreover, by design of this survey one can distinguish between:

- *short-term* academic ambitions (only for immediately after completion of the BSc degree), and
- *long-term* academic ambitions (envisaged for several years after completion of the BSc degree).

If additionally the students' academic ages (study-year) and ♀/♂ are taken into account, there are many attribute combinations with regard to which the collected raw data sheets can be classified.

As it could have been expected on the basis of [2], the proportion of students without any scientific ambitions was 'overwhelming'. Those students, who wrote that they are planning to study towards MSc or PhD degrees –even if they intend to do so only to competitively increase their own 'market value' for the purpose of climbing up the 'corporate ladder' in the commercial realm– can perhaps still be regarded as 'potential' or 'possible' academics, particularly during times of economic recession when places in the commercial industry are harder to reach. Some of those students might later change their minds and could still become members of the academic community as per second option. Most interesting are, of course, the few students who have clearly indicated already at their young age that they feel 'called' to enter the academic realm. On the basis of the above-mentioned criteria, the following pictures clearly emerged:

A male/female-comparison across all age groups –ignoring those students who did not indicate their ♀/♂ attributes– shows that the commercial-industrial inclination of male and female students is equally strong (Figure 1). However one can also see that within the minority of explicitly academically inclined students the proportion of female students is at least twice as strong as that of their male study-colleagues. It might thus seem that the future of

[*] https://sites.google.com/site/sacla2015/

academic CS could be predominantly female; however one must also take into account that the figure shows *percentages* (%). In absolute numbers the cohort of self-attributed male students (110) was still considerably larger than the cohort of self-attributed female students (33) in this survey, i.e.: male CS academics will probably continue to out-number their female colleagues for many years to come. The next picture (Figure 2) shows that, in this survey, there were only small (statistically insignificant) differences in the academic inclinations of all students across all age groups (2nd, 3rd, 4th study-year). In all groups one can find an almost equally strong desire to go into the commercial industry after graduation, i.e.: in all age groups the minority of scientifically inclined students is almost equally tiny.

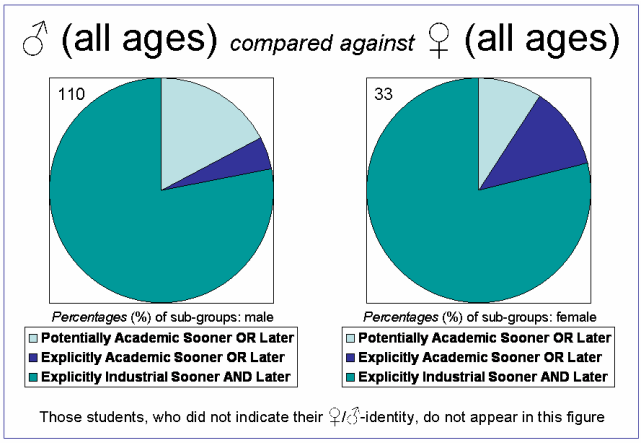

Figure 1. Academic inclination: ♂ versus ♀

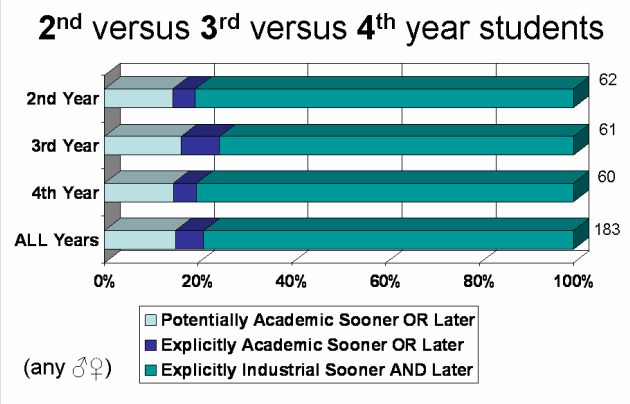

Figure 2. Academic inclination per age groups.

3.3 Independent Corroboration by Other Sources of Information

From a methodological point of view I still had to ask critically whether my findings were sufficiently 'representative', or whether they were merely accidental. To this end I looked for additional *independent* support in the following way:

For 4th-year ('honours') students the local CS department offers a variety of *elective* courses which students are not forced to take. The 'popularity' of different voluntary courses is therefore a good indicator of the students' practical-industrial versus theoretical-academic inclinations. Thereby I *hypothetically correlate* students' inclinations towards mathematical courses with their inclinations towards science in general (as it is also the case in physics and the classical engineering disciplines with their largely mathematical contents). The resulting picture (**Figure 3**) shows that particularly the *mathematical* courses were rather *un*-popular, whereas the less mathematical courses were disproportionately 'overcrowded'.[†] This picture seems to coincide well with the notorious *'crisis of mathematics*' in South African pre-university schools [7], which seems to procreate itself also amongst university students. The enrolment numbers, on which the picture (Figure 3) is based, were taken from the *previous* academic year, *not* from the academic year in which the questionnaire survey was carried out. Thus, at the time of my survey, those students were no longer 'in the system', such that the popularity of those elective modules *independently* corroborates the answers which the later students provided to my future-career survey questions. All in all, the findings seem to indicate that the majority of students considers their university mainly as a provider of practical-industrial skills, whereby the opinion that "mathematics is not necessary for a good IT job" seems to be predominant.

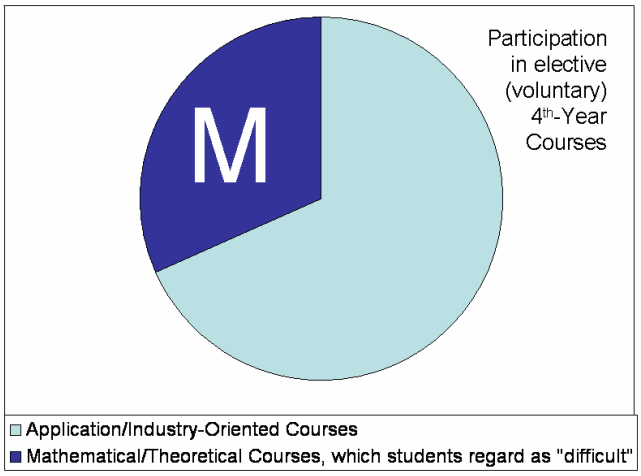

Figure 3. Popularity of elective courses at 'Honours' level.

By the way, this wide-spread anti-mathematical attitude is not only problematic with regard to the future of *academic* CS: it *also* prevents the *industrial* practice of software 'engineering' from 'catching up' with the traditional engineering disciplines and their long-established quality standards [3]. Indeed, the *commercial disadvantage of a shortage of scientificness* in the computing discipline was noticed even by industrialists like Auerbach [1].

4. SUMMARY AND OUTLOOK

All in all my survey indicates clearly that very many local students behold their university as little more than a job-training-centre for the provision of industrially 'useful skills'. The beauty of science, for its own sake, does not seem to play any role in the personal value-systems of those students any more. Moreover: similar to what Peter Seybold had written about the USA [11], also in South Africa many students are financial debtors immediately after having obtained their BSc degrees. Several students had, indeed, added such remarks about their personal financial situations as un-asked footnotes at the bottom of their questionnaire papers; however I did not reproduce those remarks in the published data sheet [5] because they did not fall into the epistemic scope of my

[†] For data protection reasons I cannot provide the enrollment details of the individual courses, which I have therefore clustered together into those two broad categories of above, "mathematical" and "industrial".

survey. For many of those students employment in industry seems to be the most viable option for off-working the burden of their study loans as quickly as possible. Also the public social prestige of wealthy businessmen might possibly be effective as an incentive, particularly for first-generation-students who are newly arising out of hitherto non-academic families. Anyway, whatever the deeper reasons of the described phenomena, at least the following *two questions* arise immediately from the data:

- Does the low percentage of scientifically inclined students in nowadays lecture halls pose any threat against the future continuation of academic computer *science* for its own sake**?**
- Does the strong industrial-practical focus of current CS curricula, which were designed for the benefits of the large majority of industrially inclined students, do *injustice* to the few –nevertheless important– students who nurture more theoretical-scientific career plans for which they would need differently designed curricula**?**

"Related to this is the normative debate about the future of the university. Should we continue to transform our universities into hierarchical corporate organizations fostering an entrepreneurial ethos...? Or should we seek to recover an academic ethos according to which the social legitimacy of science does not derive from its short-term exploitation for private gain...?", asked Hans Radder in a recent book on the modes of contemporary science [10]. In a related discourse also other authors observed an *"increasing emphasis on vocationalism in higher education and instrumentalism in research"* [9]. With the survey reported in this short-paper I have not only demonstrated the *congruence* of local and subject-specific academic issues with the global academic issues that are internationally discussed [9] [10] [12]; I have also highlighted the *problems* which could possibly arise locally for (or rather: against) the development of academic computer *science* in such a social context.

As a solution to the identified problem I can only propose the design and introduction of new, additional, separate, specifically science-and-theory-oriented curricula for preparing –from their very first day at university– a small group of particularly inclined students immediately for their MSc and PhD degrees (and subsequent academic careers) without designated 'exit point' prior to the MSc, whilst the majority of commercially inclined students would still continue to go through their industry-oriented curricula (Figure 4). In such a way one could also avoid the social conflicts mentioned in Section 1, in which particular groups of students rebel against supposedly 'unneeded' curricular topics. Similar suggestions were already published more than ten years ago, and were likewise motivated by the growing need to *defuse* the theory-versus-practice-*tensions* arising from the traditional manners of teaching of CS at universities [4].

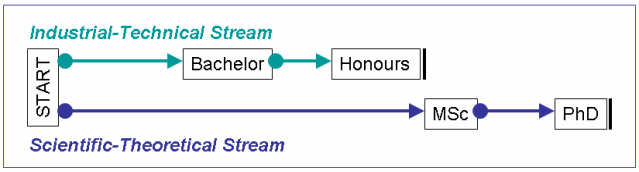

Figure 4. A 'science-first' curriculum for 'theoretical' students.

As far as *future work* is concerned the following three next phases seam to be reasonable and feasible:

- Establish an international special interest group (SIG) for *enhancing the scientification* (and theoretical formalisation) of the traditional CS curricula for especially gifted students,
- *Develop* such a curriculum within the above-mentioned SIG,
- Convince at least one university (anywhere in the world: preferably a small university characterised by organisational 'agility' and flexibility) to run a *five-year pilot study* such as to gain experiences with the novel arrangements,
- *Feed the experiences from the pilot-study back* into the SIG.

5. ACKNOWLEDGMENTS

Many thanks to the students for their voluntary participation in the survey, as well as to the reviewers of SACLA'2015 for their helpful comments. Thanks also to the ethics committee of the EBIT faculty of the University of Pretoria for the permission to conduct the survey for the purposes of this paper.

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