SACLA 2012

Educating in a Changing Environment

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Editorial

SACLA 2012 is the annual conference of the Southern African Computer Lecturers' Association. It presents lecturers at 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 2012 is 'Educating in a changing environment'.

SACLA 2012 is very proud to be associated with the Association of Computing Machinery (ACM) as an in-cooperation conference. As such we tried to set a standard of presentations such that SACLA 2012 can be regarded as a high standard forum for educators to share knowledge and expertise.

We received a total of 23 submissions. A double-blind peer-review process was followed in which each paper was reviewed by 4 anonymous reviewers. Reviewers were requested to pay specific attention to originality of contribution, relevance to the conference, technical/scientific merit as well as presentation and clarity. Based on the feedback of the reviewers, 9 papers (39%) were accepted as full papers with the full paper being published in this proceedings document. A further 10 papers (43.5%) were accepted to be presented as short papers with an extended abstract of 300 words being published in the proceedings. Five of the short papers were withdrawn by the authors upon notification of the outcome of the review process.

Pieter Blignaut (Ph.D.)
Editor
June 2012

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Using ICT to Teach ICT

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ABSTRACT

This presentation will consider various aspects of teaching and learning, and then consider the possibilities and constraints of various Information and Communication Technologies to develop heuristics for the selection of appropriate technologies and methodologies to improve student learning.

When one considers teaching and learning two aspects come into play. Firstly there is the educational paradigm - instructivist or constructivist (or preferably a combination of both). Then there is the context - one-on-one teaching, one-to-many teaching or peer learning.

When one considers media or ICT, then the aspects to consider are access and bandwidth. Access ranges from having access to a simple cellular phone, through mobile devices to desktop machines, and any permutations thereof. Bandwidth deals with the range of elements that are at one's disposal. At the lowest end of bandwidth lies simple text. At the highest end lies interactive high definition video.

So, now it is quite simple. We throw it all together. How do we instruct with technology, or allow learners to construct their own meaning, with or without the teacher, individually or in teams? And what devices do we use to deliver what kind of learning opportunities?

There are two answers to these questions, and the answers are: "It depends" and "It does not matter". "It depends" has to do with an alignment of learning outcome and instructional method. If the desired outcome is fluent, automatic response, then the method is drill and practice. If the desired outcome is independent creativity, then the method will be freestyle construction. And all the rest may be somewhere in between. Since 2000 I have been working on a four-quadrant model of integrating instructivism and constructivism in instructional design. This model has recently been tested by an American doctoral student using 200 US universities. I will share some of the results with the audience.

"It doesn't matter" comes from Tom Russell's "No significant difference" phenomenon. Russell shows that with the method being constant, the medium of instruction has no bearing on the actual results obtained. In other words, a lecture that is presented live, and a lecture that has been recorded on video, will produce the same test results in a group of learners. This means that, if you are interested purely in pass or fail results, the medium doesn't matter. The question then becomes: “So what does matter?”

The rest of this paper will consider the modalities of technology-based learning: Tutorials, drills, simulations and games and information resources. It will then consider the advantages and disadvantages of all those, and develop some heuristics of how to decide on what to use when.

Moving the Emphasis in an LMS from Management to Learning

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ABSTRACT

Learning Management Systems (LMS) are primarily used for administration, rather than for learning. Yet the features built into a modern LMS present many opportunities for creating tools that promote learning; particularly learning by doing and collaborative learning. This paper will present past and current work on exploiting the Sakai open source LMS to improve both *how* and *how much* student learning takes place at university. In recent work we examined the use of blogs to encourage learning from peers, with automated tools that adapted these blogs to highlight strong contributions, assist with searches and reorganize content. A second project analysed contributions on chat rooms and forums as an aid to understanding the dynamics of a class, such as clusters of students who interact often, the key players or knowledge hubs, and those who do not contribute. Our current research aims to create tools for short-snippet LMS input, via Web or mobile device, to increase the time spent engaging with material. Such short activities are designed to fill otherwise wasted time between lectures and the like, offering students the chance to submit or answer MCQs, contribute to a wiki on the course material, upload photos of work done, see how the time they have spent on a course compares with others and pace themselves better, and so on. Instead of social networks being the cause of poor throughput, they could become its remedy.

Categories and Subject Descriptors

H.3.5 [**Information Storage and Retrieval**]: Online Information Services – *data sharing, web-based services*; K.3.1 [**Computers and Education**]: Computer Uses in Education – *collaborative learning, computer-managed instruction.*

General Terms

Design, Human Factors.

Keywords

learning management systems, collaborative learning, mobile learning, Sakai.

1. INTRODUCTION

Ever decreasing university throughput rates have become a serious concern. Many believe that excessive use of social networks, via the Internet and mobile devices, is a major contributor towards this phenomenon. At the same time, our Internet-centric lifestyle has also led to most universities employing a Learning Management System (LMS) across all courses, in order to better administer the delivery of learning materials and, in some cases, of student submissions. This paper considers how the tools typically provided in an LMS and the popularity of social networking can be used to promote learning. Social-networking can be transformed from a throughput problem into a throughput remedy if appropriate tools and incentives can be built into an LMS. In this way we can also better utilize the ubiquity of learning management systems by ensuring they evolve from management-oriented to learning-oriented tools.

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The next section of this paper provides some background to Sakai, LMS tools and social network tools. Section 3 presents an overview of our existing and current work extending Sakai to promote collaborative learning, on-going engagement with learning materials, and time-management skills. These are discussed in more detail in the subsequent three sections respectively, followed by section 7 on usage incentives, before concluding.

2. BACKGROUND

Sakai [1] is one of the most widely used open source learning management systems. It was shown to be more usable than its strongest competitor in [2], whose experiments also showed "Four experts out of five significantly gave lower scores to Moodle." A listing of some of the tools it provides can be seen in figure 1. A number of projects have investigated its adoption and extension to better facilitate learning, and particularly collaborative learning, at both undergraduate and postgraduate level [e.g. 3,4,5,6,7]. A semantic extension to Sakai, through the integration within Sakai of Jena, an open-source RDF API [8] is reported in [9]. This focuses on the use of RDF metadata to improve searching, browsing, hyperlinking and navigating within Sakai.

This paper contends that the quality and frequency of learning can be improved by exploiting the modern student lifestyle of spending a great deal of time on blogs and social networks. Surveys such as [10] indicate there are now over 70 million blogs in existence, and over 800 million Facebook users. Several authors have studied this phenomenon [e.g. 11,12,13], indicating that it encourages writing because it satisfies our need to give personal opinions and have others read and comment on them, and encourages reading because entries are short and constantly changing. Systems that extend blogs and wikis with metadata, especially in e-learning, abound [e.g. 14], as do tools for visualising social network interactions [e.g. 15, 16] and computing network metrics such as centrality (extent of involvement), prestige (in-degree/popularity - the recipient of many messages and out-degree/expansiveness – sending many messages), closeness (to all other participants), between-ness (a link between two subnets), etc. In recent and current projects we study how blogs and wikis in an LMS can improve learning, and how social network metrics can be used to encourage collaborative learning and identify students who need help.

3. OVERVIEW

The majority of South African students tend to work on their courses only when absolutely necessary, rather than remaining up to date at all times. Most work is done alone, starting as close to the submission deadline as they believe is possible. Some help each other online or in the laboratory, but such assistance is ad hoc and unevenly distributed across the class. One of the major advantages of attending a good university is the presence of intelligent, educated classmates. We believe that proper use of an LMS can replace the "too little too late too lonely" environment with one in which all individuals share and collaborate, and reap the very rich benefits of interacting with their peers.

To encourage on-going engagement with coursework, we need LMS tools that are appealing, quick and easy to use in the short-snippet communication mode so familiar to social network and mobile phone users. A third reason why many who did well at school struggle at university is inadequate time-management skills; the inability to successfully adapt to a vastly increased workload accompanied by the novelty of adult independence.

An LMS can improve student learning by tackling all three factors: collaborative work, time management, and on-going engagement with material. We name these respectively as follows: *Touch each other, Pause to plan, Engage often – touch, pause, engage*! (with apologies to rugby fans). The next three sections outline some of our recent and current work in each of these areas.

4. COLLABORATIVE LEARNING

Most LMS tools are very well suited to collaborative learning, and in particular blogs, wikis, chat rooms, forums and Q&A pages offer up obvious opportunities. However, in our experience across a number of departments and courses at UCT, students only use the chat rooms. Unfortunately, the appealing simplicity of chat rooms is also their limitation. The lack of structure makes it difficult to separate casual chat from work-related contributions, and the latter is typically understandable only in the context of the current tut or assignment (e.g. "what did you do with the variance in Q4?") and not very useful subsequently.

In previous work [17] we studied the use of blogs as a means of learning from peers, after a survey conducted among post-graduates indicated their main problems were limited sharing, feelings of isolation, difficulty in finding sources, lack of opportunity to discuss work, uncertainty as to quality of their work, and reluctance to write up and present work. Students were required to keep their design decisions, information sources, work-in-progress, work diaries, comments and views on individual blogs, and to rate and comment on the files and snippets on each other's blogs. Blogs and snippets could be automatically annotated with icons indicating high quality, contentious, and popular contributions, and consolidate blog pages were automatically produced with items ordered according to quality, popularity or "hot topics". This was tested in the context of a small course on Research Methods where all found it easy to use. Participation rates were good, but an assignment has to explicitly require sharing for this to take place [17]. Participants also indicated they would only use collaborative technology if it was quick to use and provided clear benefit [17].

Our current work focuses on collaborative learning using wikis and forums. The forums are used in the conventional manner i.e. to post questions and answers in a clear and well-structured manner (rather than ad hoc as is currently done in chat rooms); the wiki is a study resource built *by* the class, *for* the class, along the lines of a Wikipedia collection covering the topics taught in the course. In our experience, incorrect entries are always corrected by classmates, and students are grateful for the contributions of their peers and the sharing those results from this. The challenge with these mechanisms is to encourage all the students in a class to make frequent and substantial contributions, and a number of tools are built on top of Sakai to facilitate this.

Activities	For designing, managing and delivering collaborative learning activities in LAMS
Announcements	For posting current, time-critical information
Assignments	For posting, submitting and grading assignment(s) online
Blogs	For course or project blogging or journals
Calendar	For posting and viewing deadlines, events, etc.
Chat Room	For real-time conversations in written form
Course Evaluation	For course evaluations or other surveys or feedback
Course Outline	For posting a summary outline and/or requirements for a site.
Drop Box	For private file sharing between instructor and student
Email Archive	For viewing email sent to the site
External Tool	For external tools supporting the IMS BasicLTI standard.
Forums	Display forums and topics of a particular site
Glossary	OSP Glossary Tool
Gradebook	For storing and computing assessment grades from Tests & Quizzes or that are manually entered.
Group Manager	For managing Adhoc Groups and their memberships
Maps	For using interactive Google Maps
Messages	Display messages to/from users of a particular site
Modules	For creating and organizing content modules
News	For displaying news and updates from online sources (RSS feeds)
Participants	For viewing the site participants list.
Podcasts	For managing individual podcast and podcast feed information
Polls	For anonymous polls or voting
PostEm	PostEm gradebook tool for sakai.
Q&A	For asking, answering and organising questions
Resources	For posting documents, URLs to other websites, etc.
Search	For searching content within the site or across sites
Section Info	For managing sections (e.g. tutorial groups) within a site.
Sign-up	For enabling online registration for meetings and other events.

Figure 1. Some of the tools provided in the Sakai LMS.

The first such tool produced was one for visualising forum interaction, which displayed interactions in graph and radial forms, as shown in figure 2. This enabled staff to see the extent to which individuals were contributing, and to identify clusters or groups of students who interacted frequently [18]. A student could see his/her position in this interaction graph and identify close collaborators of theirs, the extent to which they were a knowledge hub or an outlier, etc. This formed part of the SONET system that analysed and visualized forum interaction, employed a Bayesian network to determine if forum usage improved course mark, and computed social network metrics for groups and individuals, as shown in figure 3. The system computed between-ness (does this person connect mini-networks to each other), closeness (how central is this person in terms of the total distance to everyone in the network) and degree (popularity, in terms of number of people directly connected to this person). The system was tested on a Psychology 1 course of 475 forum users contributing to 69 forums on their site. Figure 4 shows that approximately 40% of users contributed, while about 60% read but did not create postings. While forum usage was not a predictor of course grade, those with high forum participation improved in the course (relative to the class average) compared with matric marks (relative to class average).

We are at present building an additional tool to show students at a glance how active they are on the site compared to others. This is based on the Pokemon game. Individuals (in smaller classes) or groups (in larger classes) choose particular characters to represent them, and these automatically evolve and downgrade according to relative position of their contribution-points in the class. Those in the bottom third of the class are shown in their base state, those in the middle third in their evolved state, and those in the top third in their highest state.

5. TIME MANAGEMENT

Time management involves having complete and easily accessible information about requirements and deadlines, reasonable estimates of task duration, and the ability to compare with others to check one's pacing. An LMS is organized on a course-oriented basis, as this is how material is created by lecturers. We are currently producing a consolidated view of Sakai tools that merges the information across all current

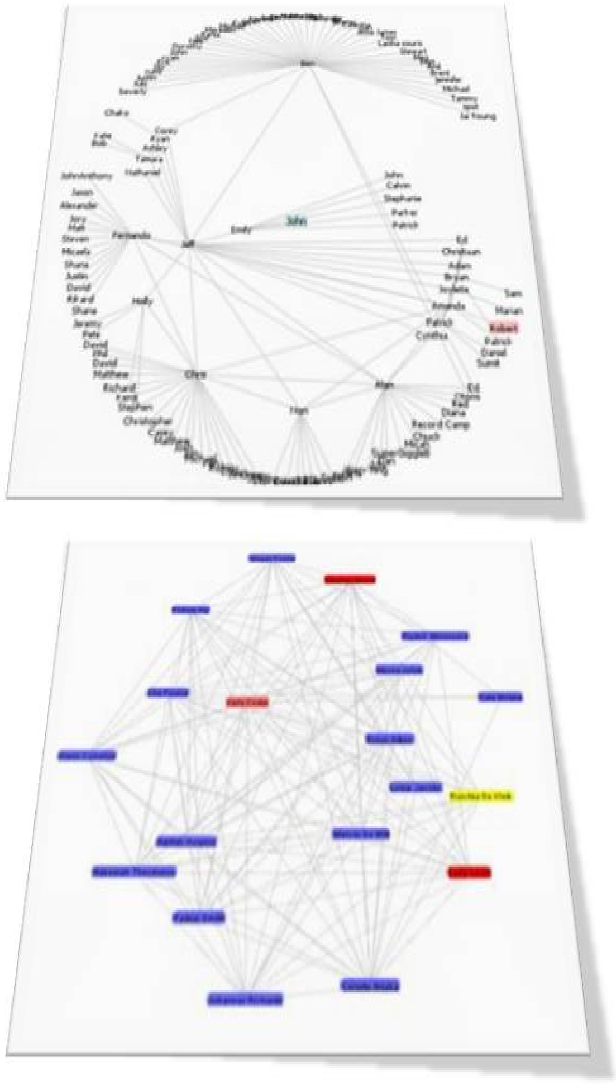

Figure 2. Radial (above) and graph (below) views of social networking on the forum

courses of a student in an additional layer above Sakai. In this view a student has a single, consolidated calendar, announcements list, etc that spans all his/her courses. This shows him/her the bigger picture as regards requirements and deadlines, and all reachable via a single click. We are extending Sakai's mobile interface to cater for quick and easy access to all new events relevant to a student – announcements, assignments, polls, etc. that have been created since they last logged on.

We are also adding the ability for a student to annotate an item with estimated and/or actual time spent on it, so that they can see how hard they need to work when, and can adjust their estimates based on past inaccuracies in time estimation. As further assistance, the system will also show the average time estimated/spent on each item by the class as a whole. This will indicate whether they are over- or under-estimators, as well as enabling them to see to what extent and where they have spent less time than others on sections of the work.

As more and more content is uploaded onto an LMS by modern lecturers, this system can also be used to study the effect of multimedia resources such as podcasts and videos on students' working habits. This is necessary to ensure that an LMS does not suffer from the problems that still plague the Web, namely over-supply of information and inability to sift through it all to separate the essentials from the rest.

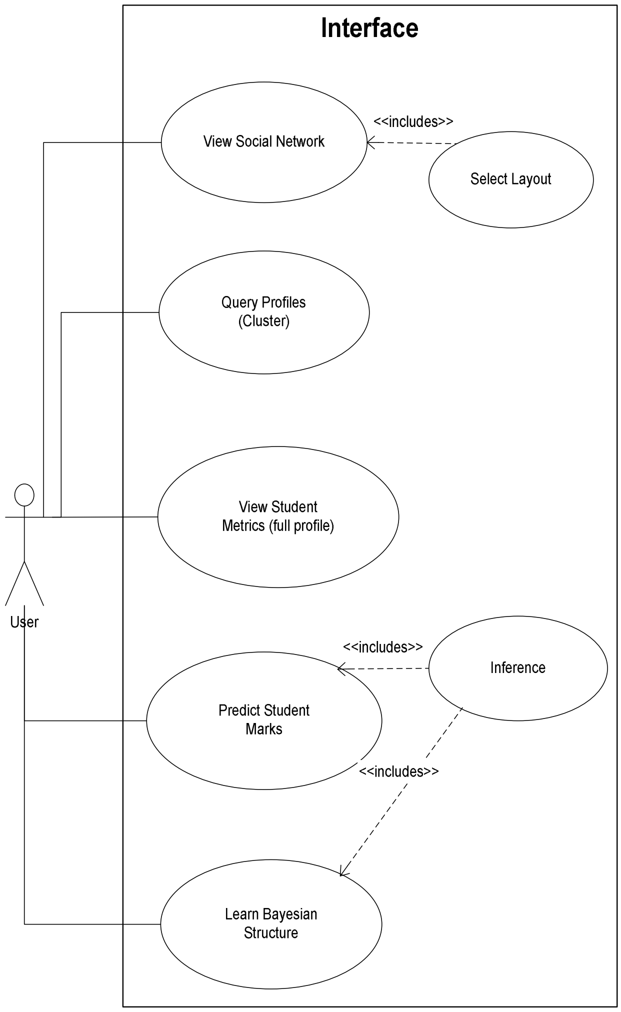

Figure 3. The SONET system for visualization and analysis of LMS interaction.

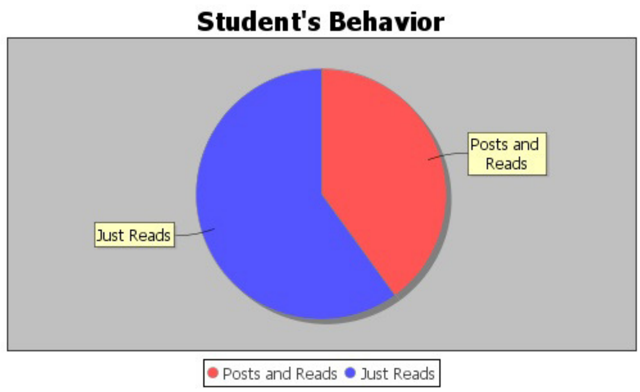

Figure 4. Proportion of forum readers in a Psychology 1 course who also posted contributions

6. ENGAGING WITH THE MATERIAL

Students of today have grown up in a world of short-snippet communication. Most popular websites, games and mobile phone interactions involve many short messages being read and written. The habit of sending, receiving and playing in short bursts, anywhere and anytime, is firmly ingrained. Students are also accustomed to instant replies, and so interacting with technology in spare moments is attractive because of the fast response. An LMS can capitalize on this by providing educational opportunities for mobile interactions that are short and fast.

Sakai automatically detects mobile access and adapts its interface accordingly. This can be used to encourage students to engage with course material in idle moments, such as between lectures or on the bus. We are currently giving points to students for wiki contributions and for answering or asking questions on forums and in multiple choice quizzes/tests.

Wiki construction can optionally be structured so as to allocate specific subsections to specific groups of students, otherwise the wiki is allowed to grow in whichever way the class prefers. Since all edits are logged, the contribution of individuals, such as those on the pass/fail border, can be viewed and examined. To encourage and help weaker students to participate, we are currently working on "push" technology, whereby students with low contribution-levels are sent messages highlighting wiki stubs and unanswered/contentious/popular forum questions, and told how many contribution-points they will score if they become involved there. The aim is also to "push" messages that encourage interaction between weak and better students.

Each wiki is created with special-purpose pages. One example of this is a "Photo Gallery" page, since many students use cameras on their mobile phones to take pictures of the board and of written work in lectures, tutorials, and learning/design sessions. Another example is a "Check this out" page, with links to videos and Powerpoint on the Web which students found useful for understanding course material. These special-purpose pages can be ordered by date or by popularity, and offer an easy way to share useful resources. A special-purpose page that is always in chronological order is the "Challenge" page, directed at the brighter students, where they pose difficult questions and set difficult problems for each other, and see which they can solve and how it long it takes before someone solves theirs.

It is typically only by requiring students to regularly and frequently do tests/exercises for marks or for DP purposes that lecturers can force their class to keep up with the work at least to some extent. One way of doing this is by having short weekly tests that are not excessively demanding of student's time but ensure that some minimal reading and understanding takes place so that at least the basics of each section are absorbed. The logistics of setting, running and marking these can be daunting, but online, open book, multiple choice questions that are automatically marked achieve what we desire of students without taking up valuable staff time.

In the case of forum and test/quiz facilities, with our approach the students are expected not only to answer but also to set questions. Questions are restricted to true/false, multiple choice and fill-in-the-blank styles. Setting questions teaches students at least as much as does looking up answers, and has the side effect of ensuring the question database continually grows and evolves. Test questions submitted by a student are associated with him/her, and are saved in batches of 10, each of which becomes a separate test that others can take. The author of a test is not known to those who answer it, and those who answer a test rate it on the basis of helpfulness and difficulty level. The Q&A facility is not used because these entries appear anonymous to the end-user (although the system logs who is involved there as it does elsewhere); in contrast, the fact that forum questions appear alongside the student's name will prevent nonsense entries there.

The section of work associated with each posting is kept as metadata, so that students can be shown how much they have contributed per section alongside the class average (number of contributions) per section. This metadata can also be used to speed up searches. The intention is that the system automatically infer which section an item refers to, so that the user simply has to change those that are incorrect and does not have to select the relevant section manually every time.

7. INCENTIVES

In addition to the challenge of creating tools and appropriate interfaces for them, it is critical that students are given incentives to use the tools, and to use them effectively. There are three fundamental ways in which students can be attracted to the collaboration, time-management and engagement facilities. They can be fun, they can be rewarding (e.g. in the case of an LMS, by offering extra marks) or they can appeal to the competitive streak in each of us.

The most obvious incentive for using LMS tools to share with classmates, and to engage with lecture material on a wiki, forum or test/quiz, is to give marks for such activities. This can either be done by making LMS participation an assignment in its own right, or by awarding a few bonus marks based on students' contributions. There are a number of difficulties inherent in a scheme that associates marks with LMS activities however. One is that this leads to these activities being seen as yet another chore for marks, jeopardising the chances of spontaneity and fun. Another is that students will be tempted to "play" the system by submitting multiple copies of items, or nonsense items. In a small class this can be detected easily; in a large course software solutions will be required to semi-automate detecting such misuse. We are currently using a broad-brush stroke approach to alleviate both these problems – relatively few marks can be earned this way, but they are bonus marks added on to whatever students achieve in assignments. In addition, an approximate rather than a precise system is used. This awards 0, 1 or 3 bonus marks according to whether the contributions-points of a student are in the bottom, middle or top third of the class.

There appears to be a healthy amount of natural competitiveness among students, and this seems well worthwhile exploiting in the context of an LMS. The Challenge Page and the fact that tests are rated by others appeal to this, as does the association of base or evolved characters to indicate relative position in class. It is hoped that the combination of these two approaches will ensure that all students utilize the new tools to the full. At present we are using the above-mentioned scheme with bonus-marks of 0, 1, or 3 for forum and test engagement; and relying on spontaneity, enthusiasm and competitiveness for wiki contributions.

8. CONCLUSION

This paper has argued for software tools and teaching practices that encourage us to utilise learning management systems with an emphasis on learning rather than administration. Earlier work examined the use of blogs to ensure that students interacted frequently by sharing ideas and resources and commenting on each other's work in progress [17], and created visualization tools to show the interactions taking place in order to identify groups that work together, key players and non-contributors [18]. We are currently investigating the use of wikis, forums, tests and question-setting to promote student learning and ensure that they engage with course material more frequently. We are also constructing tools that utilize Sakai web services to present consolidated views of multiple courses, promote better time management and facilitate short-snippet engagement with the LMS from a mobile phone. Future work will employ text mining to semi-automate associating metadata with postings, extracting work-related items from chat rooms, profiling users according to the type of content they read and contribute, and detecting misuse of the system.

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Visualization of C Data Structures for Novice Programmers

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ABSTRACT
The adage “a picture is worth a thousand words” is true in many contexts, including understanding programming concepts. We have developed an IDE, consisting of a parser, interpreter and visualizer, for a subset of the C Programming Language to facilitate the teaching and learning of data structures and memory management in the language. Utilizing a visual system to create an immersive application for novice C programmers, has been shown to lead to faster comprehension of the programming concepts, as well as greater familiarity with the vocabulary of the programming terms.

Categories and Subject Descriptors
K.3.2 **[Computer and Information Science Education]**: Computer Science Education; D.3.3 **[Programming Languages]**: Language Constructs and Features - *data types and structures*

General Terms
Languages

Keywords
Software visualization, data structures, C-style pointers, memory management.

1. INTRODUCTION
Despite the current trend of developing programming languages that are easy to use, allow rapid prototyping, and hide much of the programming complexity from the user, the C/C++ family of languages are still widely used, particularly in areas where efficiency is of utmost importance, such as systems applications, scientific programming, and game development [27]. The TIOBE Community index for March 2012 [26] ranks C and C++ as 1st equal with Java and 4th, respectively, in terms of popularity, based on the number of skilled users world-wide, courses and third-party vendors. As long as there is still demand for C/C++ programmers in both learning environments and the computing industry, students will need to be trained in these languages.

Software today typically comprises millions of lines of code. Thus, analysing the effects of changes made to this code can be a prolonged, frustrating, and error-prone task. Furthermore, to ensure that systems are built correctly and maintained, a thorough understanding of the implemented programming language is required [24]. This research focuses on providing a tool that can aid the acquisition of this in-depth programming knowledge for the C Programming Language.

One of the most powerful aspects of C and C++ is the use of pointers. The majority of most modern-day languages (Java, C#, VB) are based in a managed environment, which implies the use of a managed heap. A managed heap allows the programmer to allocate memory for use by the variables and objects, yet the programmer has no control over this memory. This approach to memory management is vastly different to that in the C/C++ languages, in that these languages provide the ability to manually maintain both the stack (for memory storage allocated at compile-time, i.e., through the use of variable declarations) and the heap (for dynamically allocated variables at runtime, typically through the use of `malloc()` in C or `new` in C++) without a managed runtime system. This adds an additional degree of complexity to the languages, yet provides the programmer with more refined, more powerful approaches for managing program resources [3].

Pointers provide a more powerful system that allows the programmer to manipulate both static and dynamic program data directly [3]. The proposed power of pointers however, often provides a hurdle to learners [24], hampering their ability to grasp the concept of effective memory management. The ability to manipulate memory is a fundamental step required in a student's understanding of how data structures are implemented and the inherent relation between pointers, and arrays or strings. Vectors, link lists, stacks, queues and other basic data structures used for programming make use of dynamic data, which has the ability to grow and shrink at runtime [3], and at the most basic level is manipulated by the proper use of pointers.

Software visualization systems in both 2D and 3D have been incorporated in a variety of fields such as software evolution, education, security, and data mining. In the field of ICT education, visualization of software engineering and algorithms can assist instructors to explain, as well as help learners to understand algorithms and programming principles and practices [9].

We make use of visualization to assist novice C/C++ programmers with learning and understanding the more difficult-to-grasp concepts, such as memory management of data structures and C-style pointers. This research is focused on creating a learning tool that allows the graphic portrayal of relevant variables and the observation of their values at each line of code during program execution.

We have, therefore, defined a grammar for a subset of the C language, called CMinor, and developed an IDE consisting of a parser, interpreter, and visualizer for this language. The system engages users by allowing them to type in their own source code, which can then be interpreted on a line-by-line basis if the user so desires. The visualizer then generates an interactive visual display of the data structures created allowing users to form a graphic mental mapping of the concepts being taught.

The remainder of this paper is organized as follows. In the next section, we discuss software visualization and virtual environments, as well as existing educational systems that make use of these techniques. In Section 3, we introduce the CMinor Studio, including the grammar, details of the IDE and parser created, and the runtime execution environment. The paper concludes in Section 4 with a discussion of the existing application and possible future extensions.

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2. SOFTWARE VISUALISATIONS AND VIRTUAL ENVIRONMENTS

Software visualization (SV) attempts to provide a tangible representation, in a visual form, of intangible software engineering concepts and algorithms, with the aim of providing better understanding and comprehension. Knight [12] gives the following definition of SV:

> *Software visualisation is a discipline that makes use of various forms of imagery to provide insight and understanding and to reduce complexity of the existing software system under consideration.*

Software visualization research in recent years has focused on two areas, namely algorithm animation, at the conceptual rather than implementation level, and program visualization, considering various implementation details of the source code, data flow, as well as runtime behaviour [6]. With respect to the former area of SV research, Karavirta et al. [11] give a comprehensive survey of animation languages and systems for software visualization. Since the CMinor application developed in this study relates directly to the latter area, here we consider literature related to program visualization only.

CodeCrawler [15], for example, is a static code visualization tool that provides lightweight 2D- and 3D-visualizations together with metric information about code structure. SV tools have also been integrated within IDEs such as Eclipse, to provide amongst others, better understanding of exception flows [23] and more efficient navigation and management of code written by other development teams [18].

Object-oriented aspects of programming have frequently been targeted for visualization. A variety of SV tools for languages such as C++ [14], Java and UML [20] are available and many different types of visualizations have been created within these programming environments. BlueJ [13] was one of the first systems developed to teach introductory object-oriented programming concepts. It utilizes a static representation of the class structure of a Java program as a UML diagram allowing the learner to interact with the class methods as well as inspect the class variable state.

The Jeliot family of applications and their predecessor Eliot, use a library of self-animating data types to represent Java user code, in a semi-automatic fashion through the use of input on various dialogs [8]. Jeliot I is a web-based application [25] based on a client-server architecture, in which the user is able to modify the appearance of the actors used to display the self-animating data types. Jeliot 2000 [17] is a complete rewrite of previous versions to cater fully for learners without any prior programming knowledge in Java. Developed as a stand-alone application, the graphical user interface for Jeliot 2000 takes the form of a theatre in which the user types in the code and presses the Play button for the animation to occur. Animations are used to visualize how the expressions are being evaluated at runtime, and all aspects of the visualizations are shown on the screen at the same time in 2-D.

Jeliot 3 [21] is closely based on the work of Jeliot 2000, retaining the GUI of the previous version. However, with modularity being the main focus, the components within the system were designed to be loosely coupled. The parser and interpreter of Jeliot 3 were redesigned, along with the self-animating library of data types to satisfy the design aim.

An empirical evaluation of Jeliot 2000 was undertaken over a full year between two groups learning Java; one without any visualization aids and the other utilizing Jeliot 2000 [17]. The results show that the improvement rate of the treatment class increased; however, the major finding was that the treatment class formed a vocabulary of verbal and visual terms of the programming concepts taught, facilitating discussions of these concepts.

With respect to animation of data structures, Java has been the target language for much of the previous research. jGrasp is an integrated approach to the visualization of Java data structures and the step-by-step execution of Java statements [1] [2]. To the best of our knowledge, tools similar to jGrasp and Jeliot, are not available for visualization of aspects of the C language, although the SWAN animation system [22] does provide an annotation scheme for C/C++ code to create animations of data structures. However, in this system the user needs to annotate the code explicitly to specify the types of animations.

A study has also been undertaken to measure the effect of varying the level of student engagement in algorithm visualization to learn simple sorting algorithms [7]. This study shows that learning increases as the level of student engagement increases. Visualizations, therefore, have a greater impact on learning when students are required to engage actively in the additional activities structured around the visualization, rather than merely viewing the visualization in a passive way.

The Virtual Environment (VE) has been proposed as a means of exploring software structures, by providing the possibility for immersion and navigation. This enables the user to interact with a representation of a familiar object. The concept of worlds in a VE can be associated with *entities* or *components* in a software system [6]. Source code may be presented and linked in a VE to improve comprehension. VEs also typically allow users to navigate through links in the world, thereby affording a faster and more intuitive interface for learning than 2D or 3D structures.

Several VEs have been designed to represent object-oriented software systems, such as ImsoVision [19] and Software World [12]. The former system represents C++ code within an immersive VE, while the latter does the same for Java code. Both of these visualization systems, however, can only visualize static properties of the code and cannot be used to represent the code state in a runtime environment.

Despite the plethora of systems for visualizing programming concepts discussed in the literature, none of these focus on the teaching and understanding of C data structures and the implications, in terms of memory management, of executing C code.

3. CMINOR STUDIO

In an attempt to provide dynamic visualization of C code at runtime, we implemented CMinor Studio, which provides an integrated environment for editing, translating, and executing C code. Code can even be executed on a line-by-line basis, if required, to allow the user to follow the exact changes taking place within the data structures in runtime memory. In the subsections below, we describe the CMinor language, together with the translation, execution and visualization components.

3.1 The CMinor Language and Translator

Since many features of traditional programming languages are unnecessary for beginner programming and visualization of data structures, a simple language has been designed for this project. The CMinor language is a subset of the C Programming Language and as such is syntactically and semantically similar to C. Features supported by the CMinor language are:

- Basic types, e.g., `int`, `char`, `bool`
- Constant types
- Arrays and array initializers
- Pointers

- Structures
- Loop statements, `while`, `do`, `for`
- If-else statement
- Functions

Features not supported in CMinor include certain operators (such as bitwise operators, ?:, +=, and so on), preprocessor directives, multi-dimensional arrays, default and `const` function arguments, `typedef`, type casts, `void` pointers, and string literals. Most of these are not used by novice programmers, and as such should not change the kind of introductory programs studied.

Allied to the lack of support for preprocessor directives, CMinor does not support the inclusion of libraries, except for a standard header file, `CMinor.h`, that extends the language by allowing an interface to the IDE to perform I/O. This header file must be included in all CMinor programs.

Translation of the CMinor source code is accomplished through the use of the CMinor translator, which comprises a traditional scanner, parser, and intermediate code generator, crafted using Coco/R [10]. Coco/R was chosen as the tool to generate the front-end for the CMinor Studio due to its ease of use, simple integration of semantic actions, and modularity regarding the symbol table. A further benefit of using Coco/R is that it can be used to construct other syntax based applications that are less like a compiler and more like a parser for a programming language, as was the case in this project.

3.2 Intermediate Code Interpreter

The output from the CMinor translator is a high-level, structured intermediate language, which is passed onto a custom-built interpreter. On its first pass over the intermediate code, the interpreter initializes an unmanaged environment, sets up the line counter, and checks for certain runtime errors, such as invalid array indices. Then, on the second pass, the individual tokens are processed to execute the user code.

During the interpretation, all runtime errors are flagged, such as *Divide-by-Zero* and *Null Pointer* exceptions. In addition, since this is a teaching tool, the CMinor interpreter throws a runtime error if variables are used without first being initialized. This restriction has been imposed in an attempt to instill good programming practice in novice programmers.

The CMinor interpreter also presents users with runtime warnings. Such warnings do not halt execution of the program, but are provided to present additional information not normally available in a C/C++ execution environment. In cases where warnings are given, the programmer is more often than not performing an operation that will return an unexpected result. An example of this is an *Array Out of Bounds* warning. Although valid in a C/C++ context, working outside the bounds of an array is not considered good programming practice and can cause unexpected results, which is not desirable in beginner programs.

As mentioned in the Introduction, an important aspect of a C/C++ implementation is the memory management. As in a traditional C/C++ environment, CMinor Studio does not have a managed heap, which means that when users allocate memory it is their responsibility to de-allocate it. As a teaching tool the CMinor interpreter provides a mechanism, once execution of the user program has terminated, to display all memory leaks. This is intended to focus user attention on the fact that runtime memory has not been managed correctly and to allow them to alter the source code to rectify the problem. As before, this is done to reinforce good programming skills.

3.3 IDE and Visualiser

The IDE for CMinor Studio provides an interactive development environment in which the user can program, run, debug, and visualize CMinor source code. In designing both the IDE and graphic visuals, we have taken into consideration a number of criteria [16] [5] that should be met when visualizing programs:

- ability to browse through the source code throughout the visualization;
- syntax highlighting of the source, as this greatly assists novices when learning a language, as well as reduces the number of mistakes [21];
- informative error messages that help direct user attention to the exact position of the error;
- simple user interface to reduce the learning curve in a new programming environment and encourage users to test code;
- adjustable speed of animations to match the pace of the user.

Taking these criteria into consideration, the CMinor IDE has been designed to be simple to use, visually appealing and easy to understand. Moreover, since this work has the same goals as Jeliot 3, i.e., creating a learning environment for novice programmers, and Jeliot's visualization techniques have been proven through various user tests to assist the learning of the Java language (see Section 2), the CMinor IDE has been built on the success of Jeliot 3, while aligning itself to the C/C++ languages. Figure 1 illustrates a simplified schematic of the panels that make up the user interface. All user controls have been placed in a ribbon-like interface at the top of the application. User customization is accomplished by providing grip bars between the Code Editor, Drawing Area and Console panels so that the size of each section can be adjusted according to the demands of the code.

As a teaching tool, the IDE provides syntax highlighting, ability to control the speed of interpretation of a program, error tracing, input and output through a console as well as the visualization of variables on the stack and heap.

In C/C++ there are two distinct runtime memory areas, the stack and heap, which must each be drawn independently according to the state of the interpreter. The visualizer's display area, therefore, has been split in two to represent the different memory areas, and the visuals produced represent contiguous memory blocks for each of these. As a variable is declared, it fills up the next available block of memory on either the stack or heap as depicted in the drawing area. This effectively creates a visual of the state of memory during execution of a program.

As discussed previously, pointers and memory management are two of the most difficult aspects of programming for learners to comprehend. Therefore, the main focus of the IDE is to produce clear visuals with regard to pointers. As a program can contain many variables and pointers, the pointer lines are drawn with a very slight opacity to increase legibility. The lines are also drawn to a grid which allows them to follow a direct route to their destination. To ensure an uncluttered visual, pointer lines

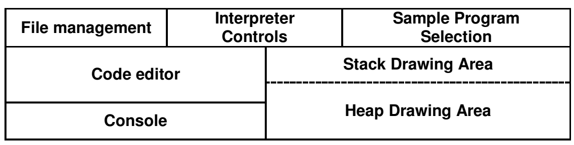

Figure 1. Structural design of the IDE.

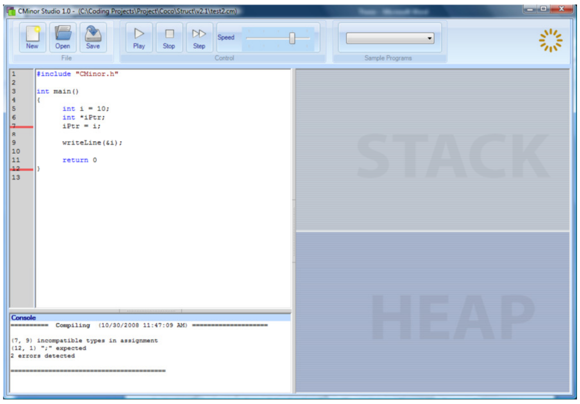

Figure 2. Lines containing errors are highlighted.

will never intersect the variables drawn on the screen.

If an error occurs during the execution of a program, the user is notified by means of a clear description of the error encountered and a red line highlighting the line of code where the error occurred (Fig. 2).

The CMinor IDE also provides the user with the ability to interact with the visualizer. As the mouse moves over a variable, the variable is highlighted. By hovering the mouse over a pointer variable, the opaque line to the variable being pointed to becomes solid. In a program with numerous variables, this highlighting of the pointer line helps clearly identify the variables being pointed to. When hovering over a variable for a longer period of time, a floating panel will appear just below the highlighted variable (see Fig. 3), giving additional details of the variable, such as its value and memory address.

As functions are called, many new variables may be introduced, which can fill up the visualization area. This makes it difficult for the user to focus on the variables currently in scope. As variables go out of scope during the execution of a program, the visualizer changes their opacity (see Fig. 4). By fading out variables that have moved out of scope, the user is able to focus on the relevant areas of the visualization.

Data structures form an integral part of many programs and as such are taught in various programming classes [3]. For a student to gain an understanding of a data structure, they must be able to visualize how the data structure is represented in memory as well as which variables are linked together. Through the ability to interact with the CMinor visualisation, data structures can be easily grasped (see Fig. 5).

4. DISCUSSION AND CONCLUSION

CMinor Studio has been incorporated into an undergraduate introductory C programming course as the first development environment. Initial results, albeit subjective, indicate that the simplified syntax of the language and additional assistance provided by the IDE shortened the learning time for coding basic C programs correctly and understanding data structures, especially those reliant on pointer variables. A greater understanding of the way memory is used in the C runtime environment was also evident from answers provided in the final module examination. More rigorous testing is currently underway to examine the benefits of CMinor Studio as a teaching tool in a more quantitative manner.

The preliminary results obtained using the CMinor Studio for undergraduate teaching, within both a practical and demonstration environment, are most promising. By utilizing this programming environment and the CMinor language, beginner programmers are able to focus on core programming concepts and obtain the deep knowledge required to become skilled C programmers.

The CMinor programming language is syntactically similar to C, without some of the more advanced features. By utilizing a

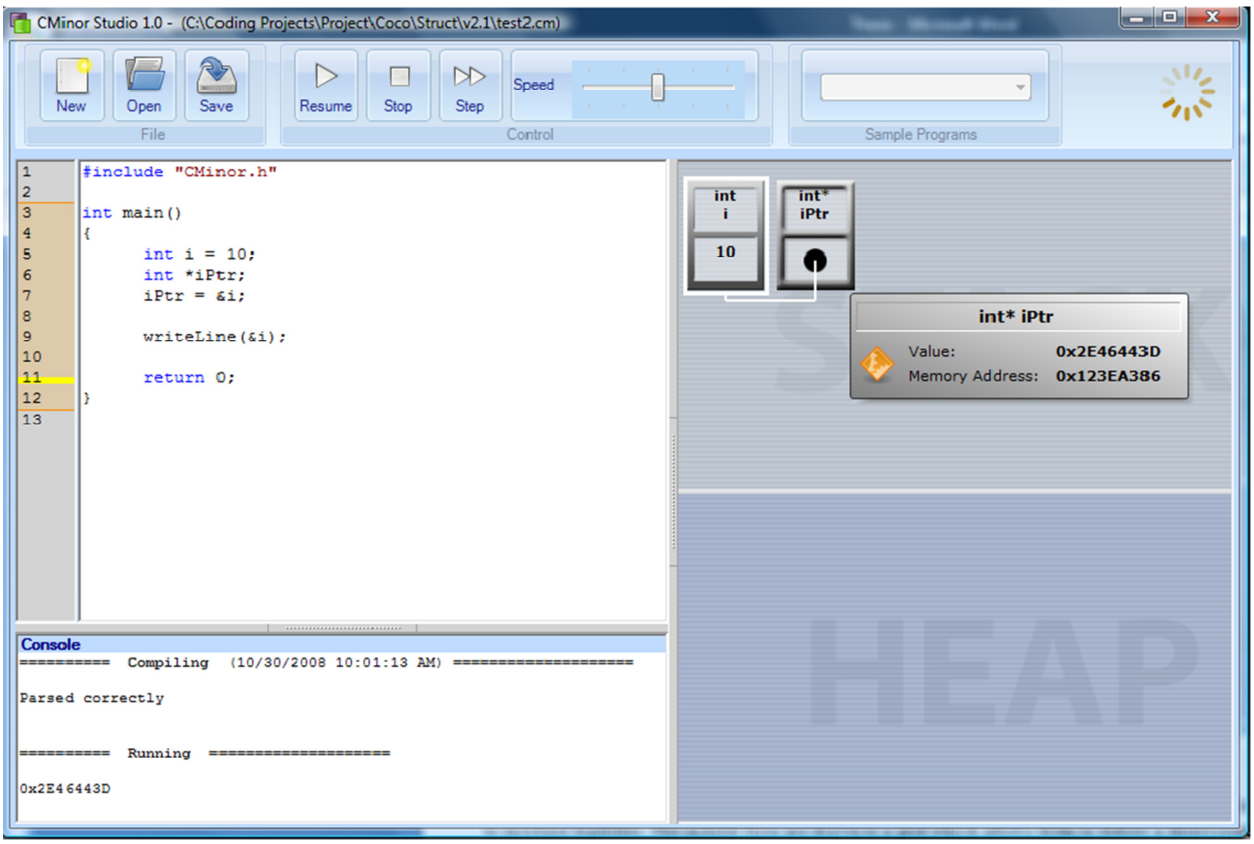

Figure 3. Additional detail for variables

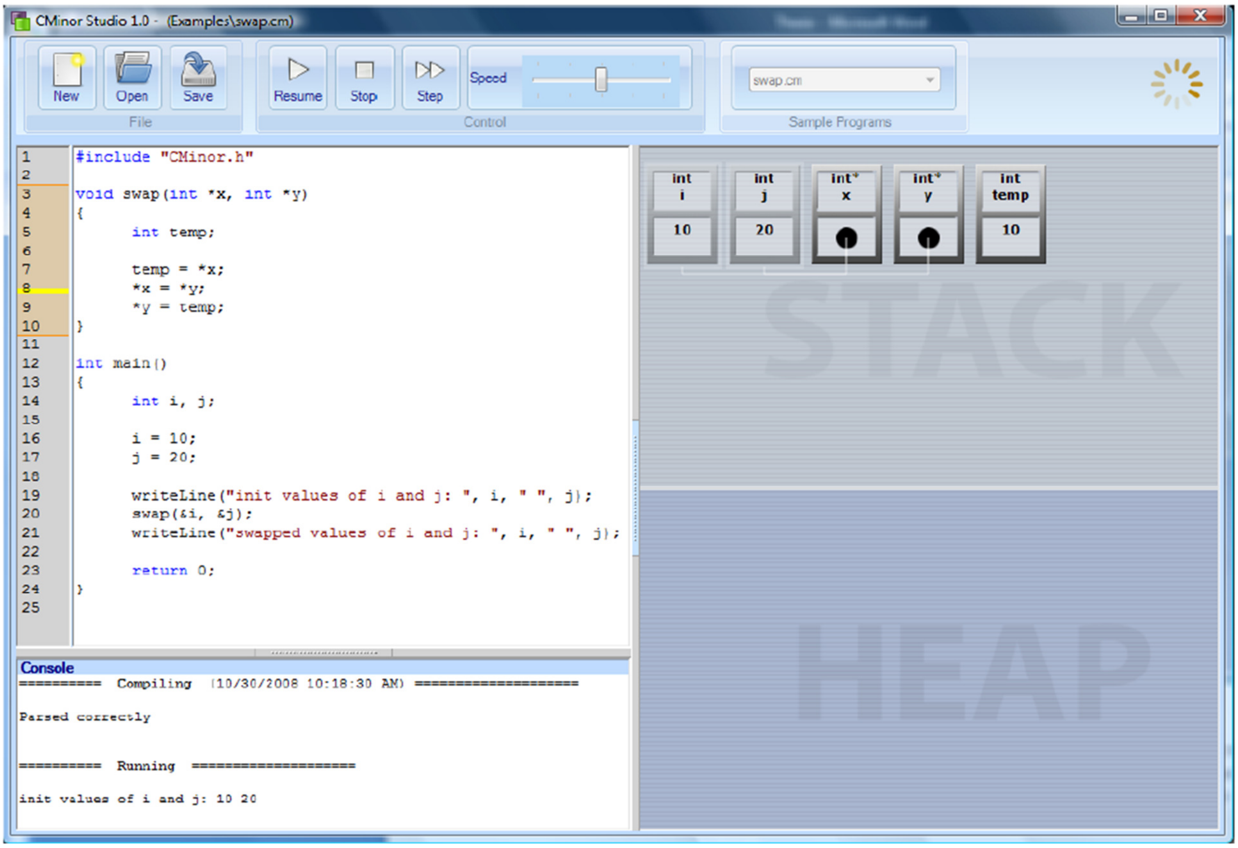

Figure 4. Variables not in scope are faded out

simple language, the novice programmer is able to focus on core aspects of C programming such as memory management, pointer handling, and data structure assembly. A parser has been designed for the language to perform syntax and semantic checks on the source code, as well as provide warnings where unsafe coding practices have been adopted. Once the code is error-free, the generated intermediate language is interpreted, on a line-by-line basis if the user so wishes and graphic visuals of the contents of runtime memory are generated by the visualizer.

In a survey of software maintenance and engineering studies [4], 40% of researchers consider SV\absolutely necessary for their work", while 42% of researchers find SV to be “important but not critical”. Thus, there is a need for effective visualization systems that reduce the complexity of learning new programming concepts, and allow new programming languages to be learnt quickly and easily. By providing an interactive 2D visual of the execution of C programs, together with the other aids that allow for ease of coding, the CMinor Studio addresses this need exactly.

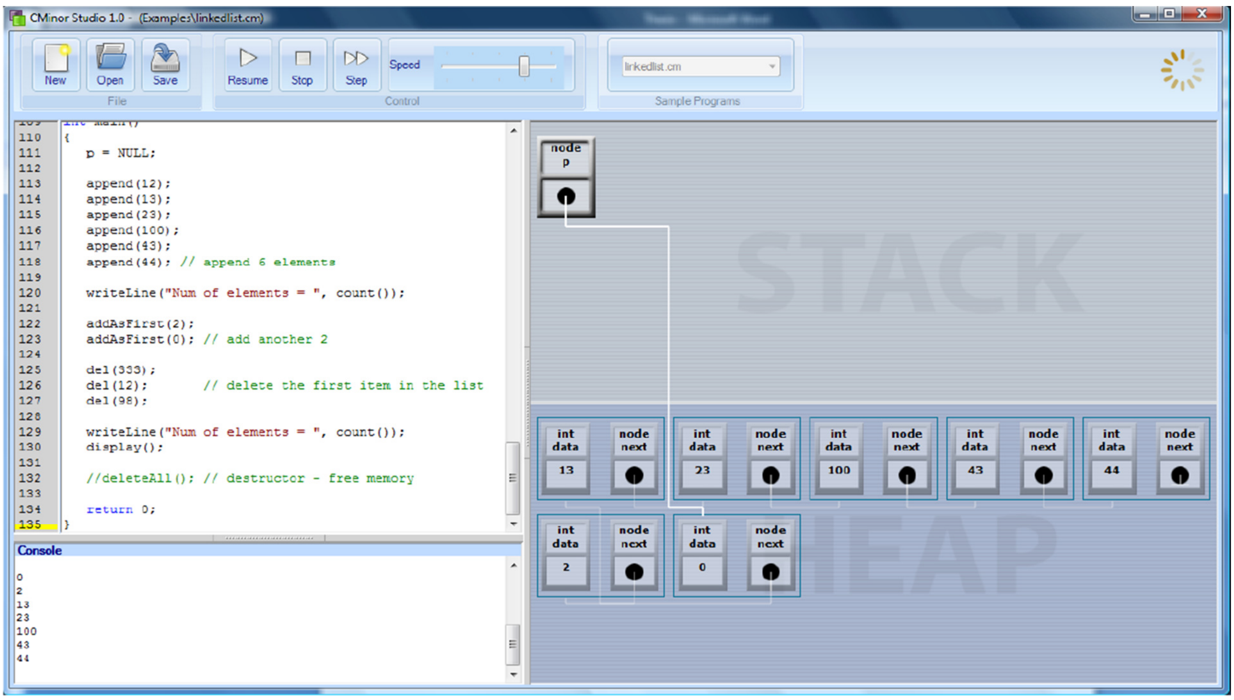

Figure 5. Linked list representation.

The CMinor Visualizer is, however, limited by the syntax of the CMinor language in terms of the kinds of visuals it can generate. To make the tool more useful for intermediate programmers, who require a greater set of features than is currently offered in CMinor, a future extension to this project would be to incorporate all of the language features of both C and C++. The inclusion of object oriented concepts would enhance this project by providing additional functionality and teaching possibilities.

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Information Visualization in Research Reporting: Guidelines for Representing Quantitative Data

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ABSTRACT
This paper presents guidelines for information visualization in quantitative research reporting in a step-wise and graphical format. The ease of use and availability of statistical packages has led to widespread use of statistical methods for information visualization. Without knowledge of statistics or easy-to-follow guidelines there is a very real potential for invalid or incorrect visualizations to be used. This compromises the validity and effectiveness of the research reporting. Here we address this deficiency by proposing a set of guidelines presented as a decision tree to guide the choice of visualization format for maximizing the effectiveness of quantitative data in academic reporting. In this paper we provide a content analysis of the literature on guidelines for statistical analysis from a knowledge visualization perspective. This was triangulated with a set of heuristics gained from experience in providing statistical support on research reporting to masters and doctoral students at the University of South Africa over a period of 11 years. The resulting analysis was integrated and contextualized to derive a set of *Guidelines for Visualization of Quantitative data in Academic Reporting* (VisQuAR). These guidelines will serve to inform the efforts of students engaged in research reporting and also to support research supervisors who have not been specifically trained in the use of statistical methods.

Categories and Subject Descriptors
E.O: GENERAL

General Terms
Graphical statistics, information visualization, knowledge transfer

Keywords
Information visualization, research reporting, quantitative data

1. INTRODUCTION
The increased importance of research skills has led to the introduction of research-related components in many postgraduate and even undergraduate courses. Many of the students taking these courses lack formal qualifications or tuition in the use of statistical methods. However due to the ease of use and availability of statistical packages, statistical methods are being widely used by these students to analyse and report their results. That this is sometimes done incorrectly is no surprise. Given the fact that some lecturers do not have a solid background in statistics the real danger is that mistakes may go undetected and uncorrected. The impact on the education of these individuals, and the body of knowledge as a whole, is difficult to quantify. It certainly provides sufficient rationale for formulating guidelines to inform quantitative visualization in academic reporting. This call is echoed by Michael Bestor writing for the Government Finance Review [6]. In his treatise titled "Graphic Communications in Crisis", he points out that an incorrectly chosen visualization could easily doom the messenger. He also points out the potential for producing visualizations which seem clever and beautiful but which fail to communicate their intended message.

The rest of the paper will be organized as follows: a brief overview of the related literature on knowledge transfer and visualization will be presented in Section 2. In Section 3 heuristic principles derived from an analysis of 110 dissertations are discussed. In Section 4 the VisQuAR guidelines are presented in an easy-to-use diagrammatic format while Section 5 concludes.

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2. VISUALIZATION
2.1 Terminology and epistemology
In discussing visualization, the terms data, information and knowledge are used in an interrelated context. In many cases they indicate different levels of abstraction and understanding, therefore it is necessary to explain the semantics of these terms in this study. According to the data, information, knowledge and wisdom (DIKW) hierarchy depicted in Figure 1 processed data becomes information, processed information becomes knowledge and processed knowledge becomes wisdom [9].

We argue that each level of processing adds subjectivity due to the subjective selection of processing procedures. The only way to manage the accountability of the process is to state the assumptions and take cognisance of the constraints at each step of the process [13]. This is not a trivial task and therefore guidelines are vital to support the novice researcher. For the purpose of this paper we will deal only with data, information and knowledge which are described as follows [9]:

- *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.

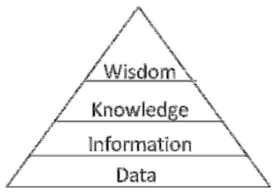

Figure 1: Data Information Knowledge Wisdom hierarchy

A researcher generates data, attributes meaning to it, and then interprets the resulting information, gaining an insight which results in him or her possessing some new knowledge [8]. This knowledge needs to be communicated (transferred) by means of academic writing.

Visualisation, as provided by graphical objects, has the potential to enhance this knowledge transfer because images are impressive, expressive and present reality [8]. Furthermore most humans interpret images far better than they do words: images address emotions and they can be inspiring, appealing, motivating and energising [7]. There are, however, risks and pitfalls in using visualisation. The risks could be both designer- and user-induced and relate to the cognitive, emotional and social human aspects [7]. For example, on a cognitive level the designer may provide an over-complex graphic or the user may not have the cognitive ability to comprehend the visualisation. It is vital that the complexity of the graphic is matched with the expectations and background knowledge of the target audience to support optimal knowledge transfer.

An epistemological perspective delineates the concept of knowledge. Academic writing traditionally focuses on propositional knowledge: a researcher *R* believes proposition *p* to be true, and wishes to convey this to his/her audience. Alston [2] argued that knowledge is "*justified true belief*". To achieve knowledge transfer it is thus necessary to give due attention to each of these components, and it implies that one cannot gain knowledge without reasoning. To foster belief we have to present *evidence*, this has to be done in a reasoned way, with a coherent argument, to provide *justification* for this belief.

Without visualization, knowledge transfer relies purely on abstract reasoning based on interpretation of the textual descriptions. An appropriate visualization can ease and facilitate the reasoning process, since the visual senses can augment the abstract reasoning process [9]. If the visualisation is done incorrectly, and promotes a flawed understanding, then *truth* suffers and knowledge transfer is compromised.

In the scenario of academic research reporting the focus must be on selecting the appropriate and optimal visualisation format. In the next section we review existing quantitative visualisation guidelines.

2.2 Knowledge transfer elements

Knowledge transfer seeks to transfer a proposition in such a way that the audience can emerge with a justified true belief of the proposition. We will now discuss each of these aspects.

2.2.1 The Proposition

The purpose of information visualization is primarily to convey ideas or messages about research data that would otherwise not be apparent – this implies that the graphical display should be meaningful, effective, unambiguous and undistorted to the researcher and to the audience [18]. In this regard Tufte [23] defined an effective graphical representation as a graph with a minimum 'ink-to-data' ratio: which suggests that any element in the graph that distracts attention from the message that the data conveys should be eliminated leaving a clear and simple, uncluttered, easily understandable message. Annesley [5] affirms the above and adds that a graph should illustrate and communicate either a trend; or a comparison; or a central value; or the distribution of the data. According to Zelazny [25] appropriate chart selection to convey a message hinges on decisions regarding the type of comparison the researchers wants to report (one of five basic types of comparisons) and the type of chart to be selected (one of five basic chart types).

The impact of the message should be strengthened by a carefully selected title and axes labels without distracting attention from the data [4]. The message should either communicate change in data over time (trend); or relations between two or more data variables; or composition of a variable or variables at any specific time; composition over time; or forecast and estimate; or detect error in recorded data.

The visualization could also be used to reveal patterns in the data. Ware [24] points out that the brain is a pattern-finding machine and an appropriate visualization can reveal hidden and relevant patterns in the data.

2.2.2 Belief, justification and truth

Kelley [17] states that a graph should depict an important message: a message that is obscured if data is presented as raw or tabulated data. He states that the graph should present the message with maximum impact. Visualizations should present conclusions in a striking way and add to the knowledge base of the target audience. Done correctly, the visualization draws attention to the most important information that underlies the research. Field and Hoyle [13] state that the underlying assumption is that data is presented honestly: using reliable data, including all relevant data, applying an appropriate uniform scale, considering zero-exclusion in the scale, and accurately defining the purpose of the presentation. However, even if the intention is pure, the choice of an inappropriate or suboptimal visualization could result in an incorrect depiction of the data, and an obfuscation of the intended message. Ware [24] warns that the human ability to identify patterns can lead to the discovery of spurious patterns, not true patterns, but something which the brain erroneously identifies from noisy data. We see two lessons emerging here: the importance of the correct visualization, and the need for the researcher to provide an accompanying explanation to guide the reader's pattern identification process.

2.2.3 Knowledge Transfer

Few [11] reasons that appropriate graph selection boils down to a decision on the message that the graph should convey – based on either ordinal, nominal, scalar data or a combination of these types. Seven types of messages are listed, namely nominal comparison, time-series, part-to-whole, frequency distribution, correlation, ranking and deviation. Once the decision on the type of message is taken, Few then suggests a decision table (mechanistic approach) for the final choice of appropriate graph type ([12]:240). Helfman and Goldberg [15] designed a semi-automated graph type selection system for selecting the appropriate graph based on what they referred to as, the characteristics of the data; the 'task' the graph has to fulfil; and the end users or audience. This development may prove useful when the usability has been improved but currently it does not address the need of a student researcher to find the appropriate visualization easily.

2.3 Published Guidelines

Many books, manuals and guidelines have been produced to explain the appropriate design and reporting of experiments using statistical analysis. According to Kelleher and Wagener [16] data visualization serves two major purposes, data analysis and data presentation. There is a vast literature on data encoding and analysis and some publications on graphical integrity and readability but these publication fail to help readers choose the right graph [10]. The following three widely used publications illustrate the fact that graph selection has often been neglected.

- Sivia [21] presents an in depth explanation of the important issues pertaining to data analysis and the selection of statistical methods in quantitative research. Examples of appropriate visualizations are mentioned but the focus is on data analysis rather than offering advice about selecting the appropriate graph.
- In the book, *How to design and report experiments,* Field and Hoyle [13] provide an in-depth explanation on research design and analysis for quantitative data. The book includes a

flowchart which can be used to select the most appropriate statistical test based on the characteristics of the data but it is necessary for the reader to have studied the book to understand the chart. Unfortunately, they do not mention how appropriate graphs for visualizing information should be chosen.

- Andrews, Klem, O' Malley, Rodgers, Welch and Davidson [3] provide a succinct and concise guide to selecting statistical techniques based on the characteristics of the data and then show how it can be done using a statistical software package referred to as SAS (*Statistical Analysis System*). SAS, version 8.0 [20] was used by Andrews et al.

The sources mentioned in this section provide useful guidance on the appropriate statistical analysis for a given data set. Most publications relate the research design to the data, some consider the purpose of the research but none provide explicit, easy to use guidance on choosing the appropriate and optimal visualization. What is lacking is concise, succinct and usable guidance that can help the student (and lecturer evaluating) make an informed choice of the correct visualization to use as dictated by the research purpose and the type of the data captured. Possibly graph selection is seen as a function of the statistical procedure but the novice researcher will undoubtedly benefit from guidelines to avoid the common errors which could lead to a break down in the knowledge transfer process.

In one of the few publications that address this issue Kelleher and Wagener [16] provide ten guidelines for effective visualization in scientific publications. While undoubtedly useful, they are on a high level and do not provide the step by step guidance novices need to fulfil their requirements for unambiguous guidance. On reflection it becomes clear that a measure of human insight is essential in supporting the choice of the appropriate visualization to ensure optimal knowledge transfer. Such a choice cannot be made in a purely mechanistic way. However, once informed decisions on design have been made the selection of the visualization format that satisfies a specific combination of selected criteria becomes important. We have to ensure that guidelines are themselves optimal and address the most common errors made by novices. The following section will review the heuristic basis for the guidelines proposed in Section 4.

3. HEURISTIC EVALUATION

The primary author is a qualified statistician involved in advising masters' and doctoral students, and their supervisors, on quantitative and mixed method research methodology and analysis strategy. Over a period of 11 years, 110 masters and doctoral candidates have been advised. Sometimes the statistician is consulted during the research design phase but in many cases the statistician was consulted only after the data had already been captured and partially analysed. This suggests that many students and their supervisors underestimate the complexity of statistical analysis or do not understand the process and the importance of planning the research with data analysis and reporting in mind. When this planning is neglected it is possible that incorrect or insufficient data will be gathered and even that the data will be analysed or reported incorrectly.

When it comes to academic reporting the words of Annesly [4:1229] strike a chord: '*a well prepared, self explanatory picture is worth a thousand words'*. The impact of visual graphics and the efficiency with which a large amount of information can be communicated to a reader calls for the graphical component of academic reporting to be carefully planned and executed.

The potential contribution of good quality visualizations to academic reporting, and the damage done by poor academic reporting, justifies a more structured approach to visualization choice. The authors (who are all involved in some way or other in the mentoring process of academic reporting) aim to address the need for clear and simple guidelines on the efficient use and development of graphical displays in academic reporting.

Here we report on a heuristic evaluation of the most common reasons why graphical displays fail to effectively and clearly convey research findings. The purpose is to determine where researchers and students commonly stray, since this will ensure that guidelines focus on the areas where they are most needed. The most common issues tend to fall into the following categories, displaying data with an inappropriate or incorrect type of graph as described into 3.1, visualizing data without a clear purpose as discussed in 3.2 and providing confusing or misleading visualizations as discussed in section 3.3.

3.1 Data type and graph mismatch

Inappropriate graph-type selection can take many forms. For example, the research message conveyed when the type of graph does not align with the *data type* suitable for the selected graph-type. Some examples illustrate the point:

1) An inappropriately selected line plot could be used for presenting the frequencies (y-axis) of the various classes of an ordinal variable (x-axis) and will thus implicitly suggest a *relationship-message* whereas an appropriate bar graph presentation of frequencies of the ordinal data variable will convey a message of *composition* of the data. Figures 2.1 and 2.2 illustrate this kind of mismatch. Figure 3.2 presents the appropriate visualization.
2) A histogram (requiring an interval scale) could be used to inappropriately present the composition of a categorical data set, when the appropriate graph-type selection would have been a bar graph. The visual message relayed to the reader is the presence of scale data and *variable distribution*.
3) Similarly, selecting a pie chart to present frequency data of a multi-choice categorical questionnaire variable will result in a confusing message being sent out because the visual message conveyed by a pie-chart is the signal of 'part-of-the-whole' (which adds up to 100% and does not exceed 100% as is the norm with frequencies of a multiple response question).

Badly-chosen visualizations can compromise the truth of academic reporting due to inappropriate graph type or data type incompatibility. For example, consider research that investigates the relationship between tobacco consumption (smoking) in the 1950s, and death due to lung cancer in the 1970s on a country by country basis. The deaths-by-consumption scatter plot and fitted regression line will be misleading and incorrect if not adjusted for population size in each country.

As mentioned, Figure 2.1 and Figure 2.2 illustrate the case of two misleading trend suggestions instead of a distribution message (Figures 3.1 and 3.2) for the same set of nominal, categorical data.

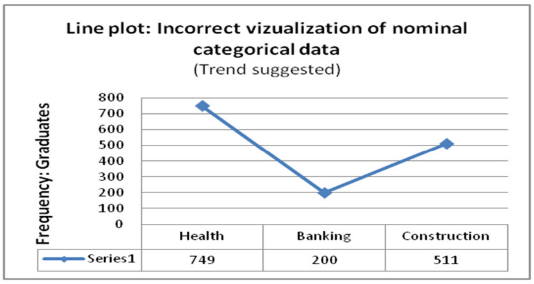

Figure 2.1: Data type and graph type mismatch

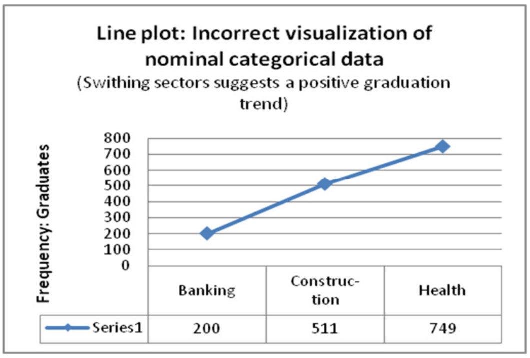

Figure 2.2: Data type and graph type mismatch

3.2 Visualization purpose unclear

If the misconception exists that the purpose of graphical visualization is to 'brighten up' an academic report, without a specific purpose to justify the visualization, the logic and quality of the report is easily compromised. Graphs are powerful tools to communicate the characteristics and behaviour of data in a nutshell and, for that reason, should not distract the focus of attention from the data itself and thereby confound knowledge transfer. Visualizing the obvious is counterproductive and deemed over-visualization. For example, two data values can be communicated with equally effective impact (and greater parsimony) in textual format. '*50 males and 63 females participated in the study*' is perfectly clear; there is no need for a visualization to enhance understanding.

In other cases, data is under-visualized. Consider that a researcher might have collected data about different occupations within employment sectors of the economy, and the number and types of degrees held by professionals employed in these sectors. An ordinary bar graph of professionals within a sector ignores the proportional distribution of degrees (See Figure 3.1). Insight into the proportional distribution of the different degree qualifications within an employment sector should ideally be displayed in a stacked bar graph (See Figure 3.2). The correct visualization can provide training agencies (such as universities) with an instant overview of the training requirements per employment sector if certain professional occupations have to be boosted and their needs targeted.

3.3 Misleading visualizations

An awareness of the implications of data scale, and, graphical x-y axes-scale considerations play an important part in addressing visual misrepresentation. Examples include:

1) Unequally spaced scale intervals on the x-y axis, which can distort the nature of the trend between two variables. Such an effect can result in a non-linear trend being depicted as linear. Figure 4 illustrates the point.

Further examples include the following:

2) The absence of a specifically defined base value as the origin of the axis (usually assumed to be the zero point)

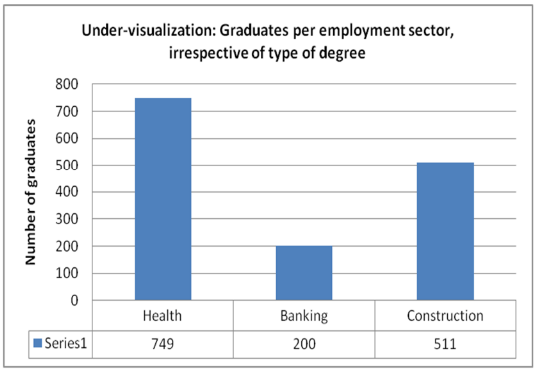

Figure 3.1: Bar graph: appropriate but under-visualized

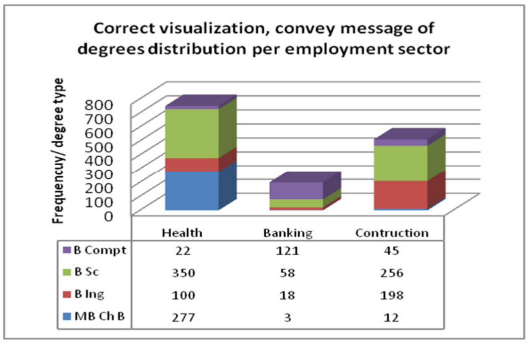

Figure 3.2: Stacked bar graph: sufficient visualization

might send out a misleading visual message. If the magnitude of scale presented on the axes is not in agreement with the magnitude of the data range, trends in the data may be marginalized or magnified out of proportion.

3) A scale other than a linear scale might underlie the data and the incorrect scale for the x-y axis system will distort trends. For example beetle-infestation-counts in grain silos would require a logarithmic y-axis if beetle infestation count were to be plotted against the depth of infestation in a silo;

4) If the x-y axes value ranges exclude values critical to the data such as points of infection, dips, peaks, in time series data, critical events might be overlooked or marginalized. If financial data is plotted as a time series and the time period of a financial depression was excluded from the axes value range, an over optimistic view of financial trends would be presented.

5) Confusing and distorted messages can also be conveyed in graphical presentations if the value range of the x-y axes does not provide enough detail to depict a change in trend. For example, if the direction or slope of the trend changes over the time period it is preferable to present it as a split

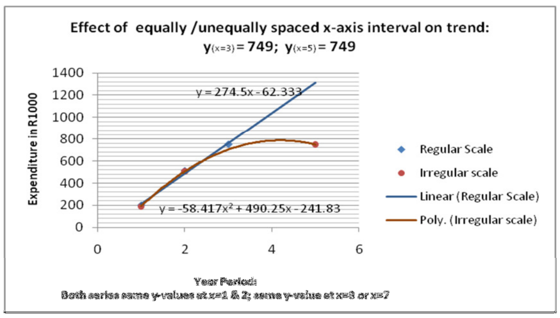

Figure 4: Ignoring unequally spaced intervals: a misleading trend message is presented

line plot rather than as a quadratic trend. For example, the pattern of sodium solution saturation changes once the saturation level of salt has been reached.

Consideration should be given to title and label descriptions of a graph. Unnecessary graphic clutter, fancy effects (3D effects) and distracting colour usage are all effects that could prevent a clear message from being communicated. Furthermore, it is necessary for the visualization to be clearly labelled so as to communicate its purpose and to convey the message the writer wants the reader to take from the visualization.

In summary it can be said that most authors agree on a core of common critical issues which require informed decisions:

- The purpose of the visualisation; or the message the visualisation should convey (truth & justification)
- The structure and type of data to be illustrated (proposition)
- The number of variables involved in the display (evidence supporting belief)
- The target audience.

These general principles have their origins in the misinterpretation, confusion or false impressions that researchers and the public have experienced due to basic graphical design principles not being adhered to. Bear in mind that when truth suffers, knowledge transfer fails and since the primary purpose of academic publishing is to allow us to "stand on the shoulders of giants" (attributed to Sir Isaac Newton) it is unfortunate when knowledge transfer fails due to a poor choice of visualization.

4. VisQuAR GUIDELINES

As mentioned previously, the need for clear and unambiguous guidelines on visualization selection came to the attention of the authors in their involvement with post graduate supervision. They noted the use of misrepresented, incorrect, or misleading graphical displays, as well as displays that over- and under-visualize data and sought to address this in a constructive way. Over time many guidelines for the appropriate selection of graphical images to represent quantitative data have been proposed. The diagram by Abela [1] was used as a launch-pad in the development of the decision diagram and this was integrated with the principles of Muller [19] and the graph-selection decision matrix approach Doumond and Vandenbroeck [10] since a decision diagram (tree structure) is deemed to be easier to use than a decision matrix.

Our guidelines are based on the three final listed criteria derived from literature and experience, and linked to a second-phase decision process presented in the decision diagram in Figure 5 and continued in Figure 6. These figures guide the researcher/student to consider the following critical issues, (based on the research study background) namely,

- The *purpose or message of the graph*. Basically four types of messages can be conveyed based on quantitative data:
    - composition or distribution;
    - relationship or trend which includes a dependent variable;
    - relationship or associations without a defined dependent variables; and
    - comparison.
- The *number of variables* required to convey the message of the graph (one, two or more variables).
- The *data type*: data can be categorized as either nominal, ordinal or scalar data, or combinations of these data types.
- The *sample size* (large or small datasets) and number of categories of categorical data (less than 8 categories; or more than eight but less than 13 categories).

If for instance, the purpose of the graph was to illustrate the composition of one, ordinal categorical variable and outcomes of the categorical variable were classified into 9 different categories – such as nine categories of professions. The appropriate option, reached by following the decision diagram in Figure 5, would be a horizontal type of bar graph.

Figure 5 describes the logical reasoning process that underlies the decision diagram presented in Figure 6. The graphical icons included in Figure 6 create awareness of graphic type development and interpretation possibilities (visualization formats). The decision path of the example discussed in the preceding paragraph terminates in Figure 5 but in other cases it continues on the graphical object selection guideline (GOSG) presented in Figure 6. In Figure 6 the data type is indicated as either 'N', 'O' or 'S', which indicates ordinal, nominal or scalar data. Note that the GOSG diagram presently provides for a maximum of two variables only.

Another example would be to find the appropriate visualization for data captured on the length and the weight of bear cubs. Here the purpose is to investigate the existence of a *relationship* between the variables. The data has *two scale* data variables, one dependent on the other. By following the path in the decision tree from Figure 5 to Figure 6 it becomes clear that the appropriate visualization for the weight of bear cubs would be a scatter or line plot.

These guidelines provide assistance in presenting data in a visual format, and can support and guide the novice researcher and help them to maximize their potential for knowledge

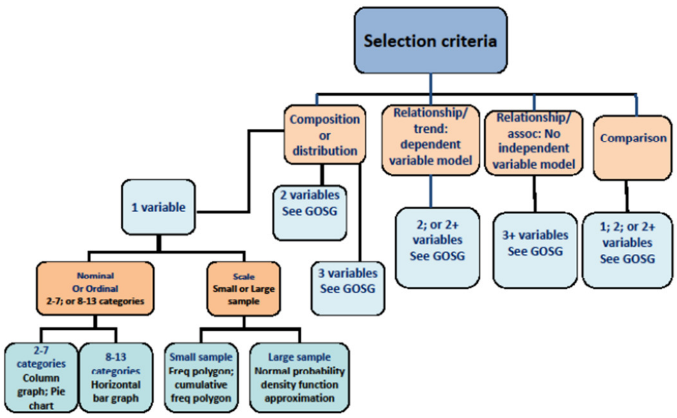

Figure 5: Selection guidelines based on purpose, number of variables, data type and data points.

Note that GOSG refers to the graphic object selection guideline presented in Figure 6.

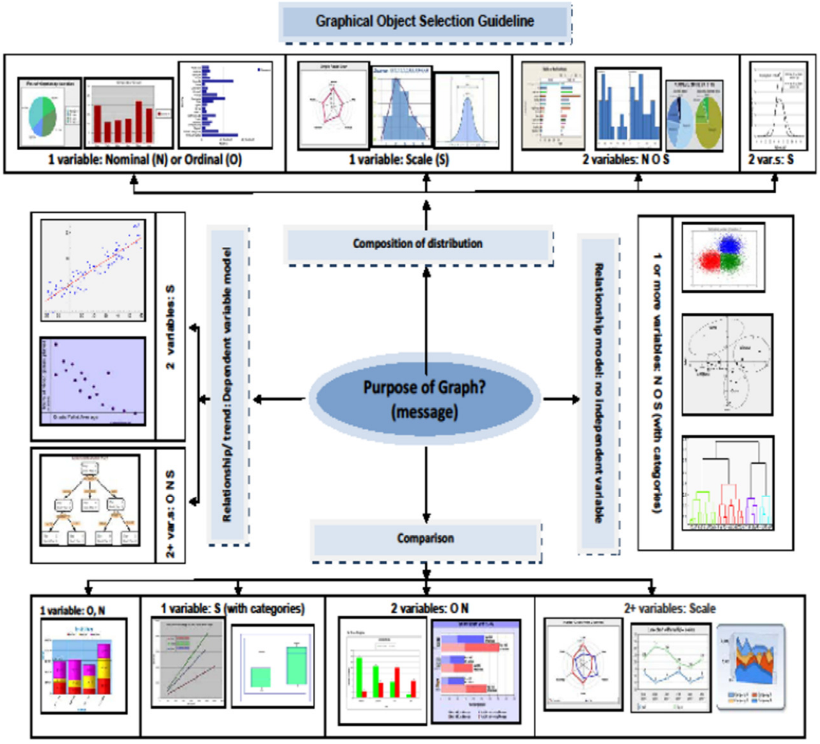

Figure 6: Graphical object selection guidelines (GOSG)

Note: The visual representation used in this compilation were found on Google Images at the addresses provided under Google Images [14] and Swiftchart [22]. The letters used to represent the data types have the following meaning: N= nominal, O=ordinal and S= scale date. For more information on the meaning of these data types we recommend the book by Field and Hoyle[13]. Note that the GOSG diagram presently provides for a maximum of two variables only.

transfer. Note that this kind of guidance is given as general principles that can be applied most of the time but exceptions and extensions are possible. Future work will consider how such exceptions can be addressed in such a framework.

5. DISCUSSION & CONCLUSION

The general principles informing visualization guidelines have their origins in the common misinterpretations, confusions or false impressions that researchers and the public have experienced due to basic graphical design principles not being adhered to. As argued earlier, such guidelines cannot be presented as a set of mechanical rules. There is an intrinsic 'resistance' to the process of appropriate graph selection through a system of automated graph choices. This resistance can be attributed to the fact that certain critical decisions and assumptions have to involve human judgment (expert decisions). Once such decisions have been taken, a subset of graph type options (or visualization formats) can be specified as viable choices.

The VisQuAR guidelines presented as a decision-tree for the appropriate visualization format-selection process is not meant to replace or negate the essential human insight component which accompanies mechanical 'rules' for the selection of visualizations for quantitative data display. However, the decision-tree does have the potential to guide students and help supervisors to evaluate students' research reports more efficiently. Furthermore it can be used as a point of departure in developing standard guidelines for evaluating student reports. The study is limited by the fact that the graphic object selection diagram presently provides for a maximum of two variables only. Future research is needed to expand the scope of these guidelines to cover more than two variables and to accommodate exceptions and extensions. Empirical testing of the decision diagrams are also required to validate the usability and the generalizability of the proposed guidelines.

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Design Patterns for Learning Formal Language and Automata Theory Topics

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ABSTRACT

Students studying FLAT topics often experience learning difficulties. This study takes an analogy from software engineering and presents a set of design patterns for FLAT topics specific to regular languages and finite transducers. A study of learning difficulties revealed that students experience problems with constructing DFAs, constructing NFAs, defining δ^* when converting NFAs to DFAs, DFA minimization, converting NFAs to regular expressions, constructing finite transducers, deriving regular expressions and constructing regular grammars. This paper presents design patterns to assist students in developing the skills needed to perform these tasks successfully.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education – *computer science education, curriculum.*

General Terms

Performance, Theory.

Keywords

Formal language and automata theory, regular languages, learning difficulties, design patterns.

1. INTRODUCTION

It is evident from the research conducted into teaching FLAT (Formal Language and Automata Theory) concepts, that these pose difficulties for both teachers and learners [1, 2, 4, 7, 9, 10, 12, 13, 14, 15]. This paper addresses some of the difficulties experienced by students when studying regular languages and finite transducers. The reader not familiar with the these topics is referred to the introductory texts on formal language and automata theory, namely, Cohen [3], Hopcroft et al. [5], Linz [6] and Sipser [11]. Merceron [8] introduces the idea of using design patterns to assist students in developing the skills necessary to construct DFAs (Deterministic Finite Automaton).

The research in this paper extends this work and presents design patterns for constructing DFAs, constructing NFAs (Nondeterministic Finite Automaton), defining δ^* when converting NFAs to DFAs, minimizing DFAs, converting NFAs to regular expressions, constructing transducers, deriving regular expressions and constructing regular grammars. Design patterns play an important role in software engineering and aim at reusing the experiences of software developers in designing software. Design solutions previously discovered are used to program solutions to new problems. In this way novices use the experiences of veteran software developers. Similarly, rules of thumb for constructing DFAs or converting NFAs to regular expressions can be identified and documented as design patterns that can be used by students to perform these tasks. Each of the design patterns is firstly presented followed by a brief discussion on the use of these design patterns.

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2. CONSTRUCTING DFAs

Figure 1 presents an extension of the design pattern in [8] for constructing DFAs. Merceron [8] also presents a design pattern for combining DFAs. A similar algorithm is used when teaching the conversion of NFAs to regular expressions and is thus not presented as a design pattern.

1. Make a list of the elements that belong to the language and those that do not.
2. Construct a DFA to accept the smallest element of the language.
3. Extend the DFA as follows:
    1. For each state check that there is one outgoing arc for each element of the alphabet.
    2. If there is a missing arc, link the arc to a state keeping in mind the definition of the language and what would have been read in to reach the particular state. It may be necessary to create a reject state at this point.
4. Test the DFA on the strings in 1. If there are strings in the language that are not accepted or vice versa make changes to the DFA accordingly and repeat steps 3 and 4.

Figure 1. Design pattern for constructing DFAs

An application of this design pattern in constructing a DFA for the following language is illustrated in Figure 2:
Given $\Sigma = \{a, b\}$ construct a DFA that accepts all words that contain a double a, i.e. aa.

The first three steps of the design pattern are illustrated in Figure 2. Note that L1 contains examples of elements in the language and L2 elements that are not in the language.

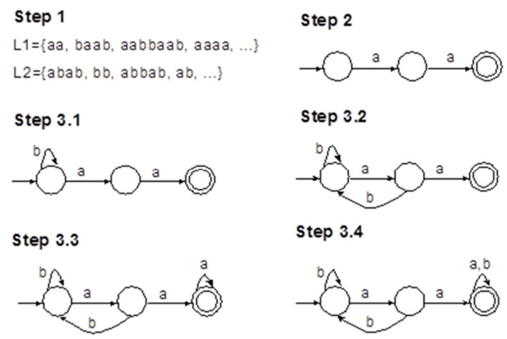

Figure 2. Example of applying the design pattern in Figure 1

3. CONSTRUCTING NFAs

Although NFAs are more intuitive to construct than DFAs, students initially experience more difficulties in constructing DFAs than NFAs due to the non-determinism associated with the latter. The design pattern for constructing NFAs is depicted in Figure 3.

1. Make a list of the elements that belong to the language and those that do not.
2. Construct an NFA to accept the smallest element of the language.
3. Extend the NFA as follows:
    1. Extend the NFA to accept larger words.
    2. In order for a string to be accepted the entire word must be read in and processing must terminate in an accept state. To reject a string do not use a reject state but use the property that a word is rejected if the entire word cannot be processed, i.e. there is no option for a character at a particular point in processing.
4. Test the NFA on the strings in 1. If there are strings in the language that are not accepted or vice versa make changes to the NFA accordingly and repeat steps 3 and 4.

Figure 3. Design pattern for constructing NFAs

Once an NFA for the smallest word is constructed, the NFA is extended to cater for larger words. It was found that students attempt to transfer their knowledge from constructing DFAs and try to put in reject states to reject words, which is not necessary in an NFA. Instead the properties of an NFA can be used to reject words not in the language. Figure 4 depicts the first three steps of the design pattern for constructing an NFA for the following language:

Given $\Sigma = \{a, b, c\}$ construct an NFA for $L(ab\ (a + c)^*)$.

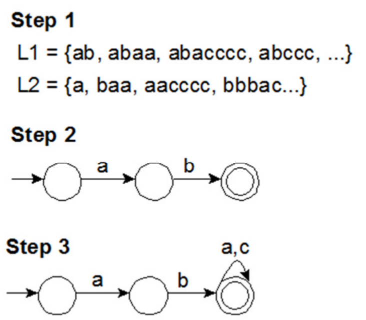

Figure 4. Example of applying the design pattern in Figure 3

The smallest word in this language is *ab*. The NFA is then extended to cater for combinations of *a* and/or *c* after the substring *ab*. A reject state does not need to be added to reject a word not in the language such as those beginning with a *b* or *c*.

4. DEFINING δ^*

In converting NFAs to DFAs students experienced difficulties with calculating δ^* when the NFA contained epsilon transitions. Consider the NFA in Figure 5. In calculating $\delta^*(1,b) = \{1, 2, 3\}$ students tend to omit state 2 and/or state 3.

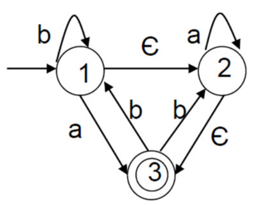

Figure 5. NFA with epsilon transition

Figure 6 presents the design pattern for defining δ^*. Consider calculating $\delta^*(1,b)$. At the end of the first step S={1}. Applying step 2 will result in 2 being included in S, S={1,2}. State 2 does not have any outgoing epsilon transitions. An application of step 3 results in steps 1 and 2 being applied to state 2, as state 1 is connected to state 2 via an epsilon transition. Applying step 1 to state 2 results in state 3 being included in S and an application of step 2 adds state 2 to S again. Applying step 4 produces S={1, 2, 3}.

In calculating $\delta^*(x, y)$:

1. Include all states *z* that are reached from state *x* by reading in a *y*, in the set S.
2. For each state *w* that can be reached from *z* via an epsilon transition, include *w* in S and apply this step to *w*.
3. Apply steps 1 and 2 to each state *z* that is reached from state *x* by an epsilon transition.
4. Remove duplicate states from S.

Figure 6. Design pattern for calculation δ^*

5. MINIMIZING DFAs

Minimizing a DFA involves firstly dividing the states into two groups, one containing non-accept states and the other containing accept states. These groups are then subdivided so as to ensure that each subgroup does not contain states that will be linked to more than one subgroup for a particular element of the alphabet. The corresponding DFA, with each group forming a state, is then constructed. Students experience difficulties with subdividing groups and often a group contains states resulting in the corresponding DFA containing states with more than one outgoing arc for a particular element of the alphabet. This can possibly be attributed to a lack of understanding of the correspondence between groups and states in the minimized DFA. The design pattern for minimization adapts the standard minimization algorithm to construct the DFA incrementally instead of grouping states and then constructing the corresponding DFA. The design pattern is illustrated in Figure 7.

1. Create two states, an initial state and a final state.
    1.1 One state will contain all the non-accept states.
    1.2 The second state will contain all the accept states.
    1.3 Make the initial state the state containing the initial state of the original DFA.
    1.4 Make the final state the state containing all the accept states.
2. Connect the two states to create an FA.
3. Repeat

    Divide the states with more than one outgoing arc for an element of the alphabet.

    Until each state has one outgoing arc for each element of the alphabet.

Figure 7. Design pattern for minimization

An application of this design pattern to the DFA in Figure 8 is illustrated in Figure 9.

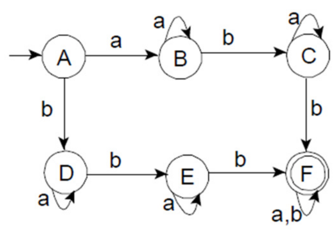

Figure 8. Example DFA

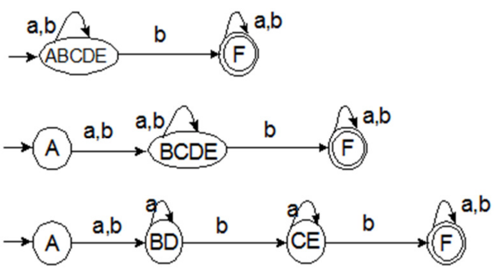

Figure 9. Application of the minimization design pattern

6. CONVERTING NFAs to REs

Converting an NFA to a regular expression involves deleting nodes and capturing the "information" along arcs until only the start state and final state remain and the corresponding regular expression is on the arc joining both these states. If the nodes are deleted in a different order each time, the resulting regular expressions will appear to be syntactically different although semantically the same. This causes confusion amongst students when reworking through examples covered in lectures and obtaining a regular expression that is syntactically different. In addition to this when deleting nodes students tend to omit information that should form part of the regular expression. This usually happens as a result of not considering all the paths that the node lies on. For example, considering state 3 in Figure 5, this node lies on four paths, namely, 1-3-2, 1-3-1, 2-3-1 and 2-3-2. Information on all four paths must be captured. For example, the arc from 1 to 2 will contain an *a* and the arc from 1 to 1 *b+ab*. Students tend to leave out one or more of these paths. The design pattern outlined in Figure 10 was derived to assist students in overcoming these learning difficulties.

This design pattern is also used in lectures when teaching the conversion of NFAs to REs. To prevent the confusion resulting from syntactically different regular expressions nodes are deleted in a left to right and top to bottom manner. For example, the order in which the nodes in Figure 5 will be deleted is 1, 3 and 2. Similarly, the nodes in Figure 8 will be deleted in the order A, D, B, E, C and F. To ensure that all paths are examined, all the paths are firstly listed and the total number of paths is calculated by multiplying the number of arcs coming into a node by the number arcs leaving the node.

When deleting nodes:

- Delete nodes in a left to right, top to bottom manner. The node connected to the final state must be deleted last.
- When deleting a node *A*:
  1. Write down all the paths *S-A-F* that the node lies on. The total number of paths will be the number of incoming arcs multiplied by the number of outgoing arcs.
  2. For each path *S-A-F* remove *A* and write down the corresponding regular expression on the arc from *S* to *F*. If an arc from *S* to *F* exists already combine both regular expressions with the union operator.

Figure 10. Design pattern for deleting a node when converting an NFA to a RE

7. CONSTRUCTING FINITE TRANSDUCERS

The design pattern for constructing finite transducers in Figure 11 builds on that for constructing DFAs. The second step in the pattern requires the same approach to be taken as when creating an acceptor for the language, but instead of including an accept state the necessary output alphabet is specified in the state that would have been an accept state in an acceptor (for Moore machines) or on the arc entering the state (for a Mealy machine).

1. Understand the function that the transducer must perform. Make a list of input strings of differing length and corresponding output strings.
2. Start by building a transducer for the smallest word and develop the transducer incrementally increasing the word length that the transducer must cater for:
   1) Create an acceptor that will accept the smallest word and place the output symbol at what would be an accept state for a Moore machine or on the arc into what would be an accept state for a Mealy machine.
   2) For each state check that there is one outgoing arc for each element of the input alphabet.
   3) If there is a missing arc insert the arc keeping in mind what output should be produced and what would have been read in to reach the particular state.
3. Use the list of input and output strings created in Step 1 to test that the transducer performs the correct function.

Figure 11. Design pattern for constructing a finite transducer

Figure 12 shows step 2 in an application of the design pattern in Figure 11 to construct a Moore machine for the following:

Construct a Moore machine that takes as input a string consisting of a's and b's and outputs a binary string that contains a 1 in the position of every second a in the string. For example an input of abab should produce an output of 00010, and an input of aaa should produce an output of 0011.

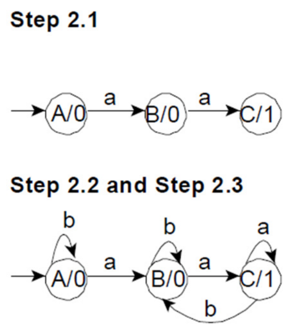

Figure 12. Example of applying Step 2 of the design pattern in Figure 11

The smallest word in this language is *aa*. In an acceptor for *aa* C will be the accept state, thus a 1 is output at this state. In Step 2.1 arcs for an input of *b* are missing for all three states. In addition to this C has a missing outgoing arc for *a*. At state A *a*'s have not been read in as yet thus *b*'s are read in until an *a* is encountered. The situation at state B is more or less the same except that *b*'s are now read in until a second *a* is encountered. At state C at least one *a* has already been read in and if another *a* is encountered a *1* should be output. If a *b* is read in at C a 0 must be output.

8. DERIVING REGULAR EXPRESSIONS

Figure 13 presents a design pattern for deriving regular expressions. This pattern uses two underlying principles, namely divide and conquer and incremental development.

Note that step 2 may not always be necessary. Suppose that a regular expression has to be derived for the following language:

> *L = {Strings composed of zero or more a's ending in a single b or strings consisting of zero or more c's and ending in a single b, e.g. aaab, ccb}.*

1. Make a list of the elements that are in the language represented by the regular expression and those that are not.
2. Divide the language into subgroups such that a regular expression can be derived for each subgroup and combined with the union operator.
3. For each subgroup derive the regular expression incrementally by developing a minimal expression and building on it.
4. Use the list created in step 1 to test that the regular expression represents elements of the language and this does not include words that are not in the language. Revise if necessary.

Figure 13. Design pattern for deriving regular expressions

Applying step 2 of the design pattern produces the following subgroups:

- G1 = {Strings composed of zero or more *a*'s ending in a single *b*}
- G2 = {Strings consisting of zero or more *c*'s and ending in a single *b*}

Step 3 of the design pattern, namely, the incremental derivation of regular expressions for G1 and G2, is illustrated in Figure 14.

G1:	G2:
1. Є	1. Є
2. a*	2. c*
3. a*b	3. c*b

Figure 14. Example of Step 3 of the design pattern for regular expressions

The regular expressions for G1 and G2 are then combined using the union operator to produce *a*b + c*b*. Consider the language *L = {All binary strings that end with an even (nonzero) number of 0's}*. In this case step 2 of the design pattern is not relevant as there is basically one group. The incremental derivation of this regular expression is illustrated in Figure 15.

1.	(00)*
2.	1(00)*
3.	(0 + 1)* 1 (00)*

Figure 15. Incremental regular expression derivation

9. CONSTRUCTING REGULAR GRAMMARS

Figure 16 displays the design pattern for constructing regular grammars. Suppose that we want to construct a regular grammar for the language $L= \{a^n b^m : n>=2, m>=3\}$. If we apply step 2 epsilon is not in the language so this production rule is omitted. Two *a*'s can be generated at variable S and another variable has to be used to generate single *a*'s after this as there must be at least two *a*'s in a word. The character *b* cannot be generated from S as words cannot begin with a *b*. This results in the following production rules S → aaA and A → aA being added to the grammar. If we apply step 4 to A the only character left to consider is *b*. The first three *b*'s can be generated at A and the remainder of the word must be generated from another variable to prevent the generation of words containing alternating *a*'s and *b*'s. The production rules A → bbbB and B → bB are added to the grammar. An application of step 5 includes B → Є in the grammar. The final grammar is listed in Figure 17.

1. Make a list of elements that are in the language and those that are not.
2. If epsilon is in the language include the production rule S → Є.
3. For each element of the alphabet consider whether the rest of the word must be generated at S or another variable. Add the corresponding production rule.
4. Repeat step 3 for each new variable introduced.
5. Consider the word generated thus far when each variable V is evoked. If the partially generated word is in the language add the production rule V→ Є.
6. Similarly, if the partially generated word with the terminal t appended to it is in the language, add the production rule V → t to the language.
7. Test the grammar on strings in step 1. If the grammar does not generate strings in the language or generates strings not in the language change the grammar accordingly and retest.

Figure 16. Design pattern for constructing regular

S → aaA
A → aA | bbbB
B → bB | Є

Figure 17. Grammar for $L= \{a^n b^m : n>=2, m>=3\}$

10. DISCUSSION

These design patterns were used in the instruction of a third year course on formal language and automata theory which forms part of the curriculum for students majoring in Computer Science as part of a three year Bachelor of Science degree. The design patterns were presented during lectures and students were required to apply them in tutorials. An empirical evaluation of these design patterns was conducted by monitoring student use of the patterns during tutorials. Students found the design patterns for constructing DFAs, calculating δ* and deleting nodes in converting NFAs to REs the most beneficial. Students found the step-by-step approach for constructing DFAs effective as it reduced the options when constructing DFAs thus making the process less ambiguous at each stage. The design patterns for calculating δ* and deleting nodes in converting NFAs to REs assisted students in not omitting essential states and paths respectively. While some students found the design pattern for minimization helpful, others found the process overwhelming when applied to complex problems. Ways of improving this design pattern will be examined.

11. CONCLUSION

It is well known that students studying formal language and automata theory experience difficulties. This paper presents eight design patterns to assist students in learning certain FLAT topics, namely, regular languages and finite transducers. Students found the use of design patterns helpful.

The design patterns for constructing NFAs, calculating δ* and deleting nodes when converting NFAs to DFAs were found to be the most useful. Given the positive response to the use of design patterns, future work will look at developing design patterns for other FLAT areas such as context-free languages and Turing machines.

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Using Bloom's Taxonomy for the Teaching and Assessment of Computer Science Courses

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ABSTRACT
Bloom's taxonomy was originally developed to ensure that assessments evaluate more than just the recall of facts. As such the taxonomy presents six cognitive levels for this purpose, namely knowledge, comprehension, application, analysis, synthesis and evaluation. Since its inception there have been revisions to Bloom's taxonomy including an extension of the taxonomy for computing courses. Furthermore, the taxonomy has been used for other purposes such as teaching of courses, setting practical questions and student self-assessment. This paper examines the use of Bloom's taxonomy in the teaching and assessment of Computer Science courses. An undergraduate Computer Science module, namely, Artificial Intelligence and an Honours level course, Genetic Programming, are used to demonstrate this.

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

General Terms
Measurement, Experimentation.

Keywords
Blooms taxonomy, teaching, assessment, computer science.

1. INTRODUCTION
There has been a fair amount of research [2, 4, 5, 6, 7, 8, 10, 11, 12, 13] into the use of Bloom's taxonomy in Computer Science education. A majority of this work has focused on the use of the taxonomy for assessments in programming courses. Bloom's taxonomy was firstly introduced in 1956. Over the years the taxonomy has been revised and has been used for purposes other than assessment including development of curricula and teaching methods. This paper shows how Bloom's taxonomy can be used in the teaching and assessment of Computer Science courses.

As most of the previous work focuses on entry level programming courses, this paper illustrates the use of the taxonomy for the teaching and assessment of a third year undergraduate module and an Honours level module.

The following section introduces Bloom's taxonomy. Section 3 describes previous applications of Bloom's taxonomy in Computer Science education. Section 4 demonstrates the use of the taxonomy for both teaching and assessment purposes.

2. BLOOM'S TAXONOMY
Bloom's taxonomy provides a classification of learning objectives [3]. These objectives are separated into three domains, namely, cognitive, affective and psychomotor. Different handbooks were published to document each of the domains. The taxonomy for the cognitive domain, published in [3], has become commonly known as Bloom's taxonomy. This taxonomy describes six cognitive levels namely, knowledge, comprehension, application, analysis, synthesis and evaluation. These levels are presented in the form of a pyramid (Figure 1) with the apex of the pyramid representing the highest cognitive level and the base the lowest [1].

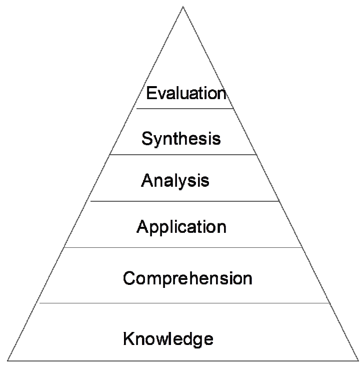

Figure 2. Bloom's taxonomy

The knowledge level is the lowest cognitive level and is the ability of memorization and the straight forward recall of facts. This knowledge encompasses definitions, classification, theories and methodologies amongst others. Examples in the programming domain include recalling the syntax of a `for` loop or the steps of a bubble sort.

The comprehension level assesses the ability to understand knowledge. Terms used in the assessments for this level include organize, compare, translate and interpret. For example, predicting the output of a piece of code or algorithm.

The application level refers to solving new problems using existing knowledge, for example in applying a known search algorithm to find a solution to a new problem.

The analysis level is the ability to divide knowledge into parts based on certain criteria. In the programming domain this would involve assessing a student's ability to solve a problem by dividing the problem into constituent parts and solving each sub-problem [13].

Synthesis refers to the ability of combining components together to provide a solution. For example, combining the knowledge of different programming concepts to create a program to solve a particular problem, e.g. the knowledge of file processing, text processing, data structures and sorting need to be combined to open a file of records, store them in memory, sort them and write the output to the screen [6].

The evaluation level is the ability to assess quality or ideas. An example from the domain of programming would be to evaluate a piece of code for accuracy and efficiency.

Anderson and Krathwohl [1] revised the original taxonomy. These revisions included renaming the levels, introducing a new level create and combining the analyse, evaluate and create

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levels into a single level at the highest level of the taxonomy. This is illustrated in Figure 2. The create level is the ability to create a new structure or pattern using existing components. Terms used in the assessment of this level include generate, plan and produce. For the programming domain an example would be the derivation of a new algorithm [6].

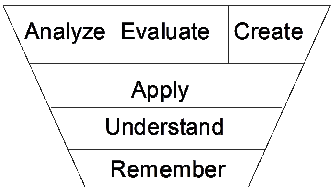

Figure 2. Revised Bloom's taxonomy

Johnson and Fuller [5] investigated the appropriateness of Bloom's taxonomy for computing courses. This study revealed that in order to cater for Computer Science education the taxonomy must be extended to include an additional level, namely higher application, as the highest cognitive level of the taxonomy. This is illustrated in Figure 3. According to Johnson and Fuller an overall application is the core output of computing and hence computer science education and thus this level is necessary. The following section examines the previous work applying Bloom's taxonomy in Computer Science education.

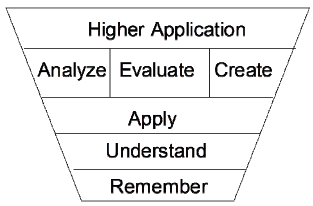

Figure 3. Bloom's taxonomy for computing

3. PREVIOUS APPLICATIONS OF BLOOM'S TAXONOMY IN CS EDUCATION

While Bloom's taxonomy has been predominately used for developing assessments for Computing Science courses, there have been applications of the taxonomy in the development of curricula [6] and teaching methods [7]. Furthermore, the taxonomy can be applied to specific CS topics, overall courses, or the entire degree programme [5]. This section provides an overview of the use of Bloom's taxonomy for CS education.

Khairuddin et al. [6] have used Bloom's taxonomy to improve the assessments for a software engineering course. Scott [10] gives examples of how Bloom's taxonomy can be used to set exam questions for Computer Science topics. The main aim of the Bracelet project was to ascertain learning difficulties experienced by first year programming students [12]. End-of-semester examinations were used to assess this. Bloom's taxonomy was used to set these examinations. Thompson et al. [13] also use Bloom's taxonomy to design examinations for introductory programming courses.

Lister et al. [8] and Box [4] use Bloom's taxonomy to derive a grading scheme for object-oriented programming courses. These schemes award a pass for the knowledge and comprehension levels of the taxonomy, a credit or distinction for the application and analysis levels, and a higher distinction for the synthesis and evaluation levels.

The study conducted by Alaoutinen et al. [2] focuses on enabling students to follow their own development. In this study Bloom's taxonomy is used for self-assessment by students. Students were required to rank a list of programming concepts according to Bloom's taxonomy and so assess their perceptions of these topics.

Starr et al. [11] have employed Bloom's taxonomy to specify the outcomes of a programming course. This is achieved by categorizing the topics to be taught according to the cognitive levels of Bloom's taxonomy.

Machanick [7] applies Bloom's taxonomy to the teaching of three Computer Science courses, namely Data and Data Structures, Algorithms and Architecture and an Honours level course Computer Architecture. This study uses the taxonomy to order teaching material when presenting these courses.

Rutkowski et al. [9] use Bloom's taxonomy to identify the cause of poor performance circuit theory laboratories. The taxonomy was used to analyse the problems used for the laboratories. The study revealed that the cause of the learning difficulties was that students did not possess the knowledge described by the lowest level of the taxonomy. This was remedied by using Bloom's taxonomy to set laboratory exercises.

4. BLOOM'S TAXONOMY FOR CS TEACHING AND LEARNING

Based on the review of research into the use of Bloom's taxonomy in CS education presented in the previous section, it is evident that the taxonomy is effective in developing teaching methods, and assessments such as examinations for Computer Science courses. In previous work the taxonomy has been used for one of these purposes. This section examines how the taxonomy can be used for both these purposes in a single course. This section describes the use of the taxonomy for the teaching and assessment of two courses, a third year undergraduate module and an Honours course. The undergraduate course is Artificial Intelligence. The course at Honours level, namely Genetic Programming, was chosen as due to the change in level the teaching and learning outcomes are different. Furthermore, continuous assessment is employed for this module.

4.1 Artificial Intelligence Course

This course is offered at the third year level of a three year major in Computer Science. The prerequisites of this course are a course on object-oriented programming and a course on data structures. The topics covered are listed in Table 1.

Table 1. Topics covered in the Artificial Intelligence course

1.	Introduction to Artificial Intelligence
2.	State Space Representation and Search
3.	Game Playing
4.	Knowledge Representation
5.	Prolog Programming
6.	Neural Networks
7.	Expert Systems
8.	Fuzzy Logic
9.	Genetic Algorithms

The course is taught over thirteen weeks with three 45 minute lectures and a three hour practical/tutorial (depending on the nature of the course) per week. The final assessment for the course is a three hour written examination at the end of the course. Assessments during the thirteen week period include two written tests and three assignments.

Bloom's taxonomy is applied to the instruction of each topic in the course and the setting of the final examination of the course. The lower three levels of the taxonomy are used to present materials during lectures. Knowledge is presented to students in the form of definitions and algorithms corresponding to the lowest level of the taxonomy. An example illustrating the definition or algorithm is then presented facilitating the comprehension of it. Students are then required to apply the algorithm or method to solve a different example, corresponding to the "Apply" layer of the taxonomy. Tutorials and practicals are used to reinforce this level of the taxonomy and focuses on the next level combining the processes of analyse, evaluate and create. Assignments are used to achieve the highest level of the taxonomy, namely, "higher application". It may not be possible to implement the higher application level for all topics in a semester course.

The application of Bloom's taxonomy will be illustrated using the topic of game playing. Table 2 lists subtopics covered in lectures and the level of the taxonomy that these correspond to.

Table 2. Lecture breakdown for the game playing topic

Subtopic	Taxonomy Level
Introduction to game playing	Remember
Example of game and game space	Understand
Introduction to heuristics for game playing	Remember
Example: Calculating heuristic for tic-tac-toe	Understand
Minimax algorithm	Remember
Example: Application of the algorithm	Understand
Exercise on minimax	Apply
Alpha-beta pruning	Remember
Example of alpha-beta pruning	Understand
Exercise on alpha-beta pruning	Apply

The tutorial on game playing includes the following exercises:

- Deriving a heuristic for a new game.
- Application of the minimax algorithm to game trees.
- Application of the minimax algorithm with alpha-beta pruning to game trees.

The assignment question requires students to implement the minimax algorithm and the minimax algorithm with alpha-beta pruning for the game of tic-tac-toe in a programming language of their choice.

Table 3 presents a breakdown of the examination questions for the final examination for the course. A brief description of the question and the levels of the taxonomy that the question covers are listed.

Table 3. Artificial Intelligence examination breakdown

Question	Description	Taxonomy Levels
Q1	Students were required to specify the most appropriate technique/s to use to solve different problems and substantiate their choice.	Knowledge Create
Q2.1	Students were required specify the following for an unseen AI problem: • State in a state space representation. • Moves in the representation. • Heuristic function if an informed search is used . • Most appropriate search to use to solve the problem.	Knowledge Apply Analyze-Create
Q 2.2	Application of the minimax algorithm with alpha-beta pruning.	Knowledge Understand Apply
Q3	• Construction of a semantic network for an unseen problem • Application of backward chaining and resolution to find a solution to an unseen logical problem.	Knowledge Understand Apply
Q4	Prolog programming • Traces • Writing Prolog predicates • Writing Prolog programs	Knowledge Understand Higher application
Q5	• Students were required to specify the levels of reasoning for different machine learning techniques. • Students were required to identify the most appropriate neural network for a particular application, train the neural network and describe what the output of the neural network will be in the case of noisy data.	Knowledge Understand Higher Application

4.2 Genetic Programming Course

This course is an Honours level course covering the topics listed in Table 4.

The course is taught over a thirteen week semester. There is a 90 minute lecture a week with a practical exercise that must be completed which contributes to the assignments for the course. Assessment is continuous and includes two theory tests and five practicals and assignments. As assessment is continuous, in this case Bloom's taxonomy is applied to the instruction and assessment of each topic. The lectures cover the knowledge, understanding and evaluation levels of taxonomy, practicals the apply and create levels, assignments higher application levels and theory tests knowledge, understanding, apply, and the analyse, evaluate and create level.

Table 4. Topics covered in the GP course

1. Introduction to genetic programming
2. Initial population generation
3. Population evaluation
4. Selection methods
5. Genetic operators
6. Control models
7. Reporting on the performance of GP systems
8. Symbolic regression problems
9. Classification problems
10. Evolving game playing strategies
11. Evolving recursive algorithms
12. Evolving iterative algorithms
13. Evolving modular programs
14. Evolving algorithms that use memory and data structures
15. Architecture-altering operations
16. Limitations of genetic programming

For example, consider the introductory genetic programming topics, namely, the genetic algorithm and control modules, initial population generation, evaluation, selection and genetic operators. In lectures the definitions and algorithms for each subtopic and examples to facilitate an understanding of each subtopic is presented. In the case of initial population generation the different methods full, grow and ramped half-and-half are described and illustrated. The corresponding practical component will require the student to implement these methods for a particular application. Similarly, the practical component for genetic operators will require students to build on the previous practicals on initial population generation, evaluation and selection and implement the crossover, mutation and reproduction operators.

The assignment will involve combining the components developed in the practicals in the overall GP algorithm, use the algorithm to solve a problem, fine tune the genetic parameters for this purpose and report on the performance of GP for solving this problem.

Examples of test questions for these introductory topics include:

- The genetic programming algorithm usually finds a solution by firstly converging to an area of the search space. How can one detect whether algorithm has converged?
- Briefly describe the following genetic operators. In each case also explain how the operator will affect the convergence of the GP algorithm: crossover, create, inversion.
- Define the term selection pressure. How can the selection pressure be increased or decreased when implementing the tournament selection method?
- Describe various GP components, e.g. representation, evaluation function, for an unseen/similar application.

5. CONCLUSION

This paper investigates the use of Bloom's taxonomy in Computer Science education. In previous work the revised taxonomy has been used for the assessment of Computer Science modules. It has also been employed for the teaching of CS topics. This paper examines the combination of both these aspects and presents a model for utilizing Bloom's taxonomy for both the teaching and assessment of Computer Science modules. This is illustrated using a third year undergraduate and an Honours module. An empirical evaluation of the approach was conducted as part of the end of the semester course evaluation for each course. Student feedback was generally positive. From the comments made by students taking the Artificial Intelligence course it was evident that a majority of the students found the tutorials helpful and necessary to reinforce what was covered in lectures and obtain an understanding of the concepts. Students found the practicals in the Genetic Programming course effective in assisting them visualize the abstract concepts.

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An M-Learning Strategy for leveraging learner participation: Using WhatsApp Mobile messaging at a South African University of Technology

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ABSTRACT

One of the most complicated academic endeavours in transmission pedagogies is to generate democratic participation of all students and public expression of silenced voices. While the potential of mobile phones particularly, mobile instant messaging (MIM) to trigger broadened academic participation is increasingly acknowledged in literature, integrating MIM into classrooms has often been confronted with academic resistance. Academic uncertainty about MIM is often explained by its perceived distractive nature and potential to trigger off-task social behaviours. This paper argues that MIM has potential to create alternative dialogic spaces for student collaborative engagements in informal contexts, which can gainfully transform pedagogical delivery. An instance of MIM run on handhelds, WhatsApp, was adopted for an Information Technology course at a South African University with a view to heighten lecturer-student and peer-based participation and inclusive learning in formal (lectures) and informal spaces. The findings of the study suggest heightened participation, the fostering of learning communities for the creation and exchange of knowledge and emergent transformation of student learning styles. However, the concomitant challenges of using mobile messaging included mature adults' resentment of collapsed contexts, which WhatsApp rendered and student ambivalence about MIM's wide scale rollout in different academic programmes.

Categories and Subject Descriptors

K.3.1 **[Computer Uses in Education]** Collaborative learning, Computer-assisted instruction (CAI), Distance learning

General Terms

Human Factors, theory, performance, verification

Keywords

WhatsApp, mobile instant messaging, digital inclusion, academic participation, nomadic learner

1. INTRODUCTION

The surging popularity of mobile devices as technologies that could support collaborative learning environments has been a staple discourse among researchers in the last decade. This growing interest in these handhelds constitutes a clear recognition of the power of networked intelligent devices to foster situated learning, collaborative knowledge generation and engagement with content [3, 15, 8]. Echeverría, et al. [8] articulate the multiple purposes of mobile devices documented in academic literature as follows: access to content, supplementation of institutionally provided content and acquisition of specific information, fostering discussion and information sharing among students. The thesis of this paper is that mobile phones augment traditional instructional delivery by rendering alternative, dialogic learning spaces that breach the transactional distance between academics and students. Despite this tremendous potential to activate collaborative learning environments that generate deep lecturer-student and peer-based engagement with content, the ability of mobile devices to trigger more democratic participation has been sub-optimally exploited in academic literature.

One of the least exploited functionalities of mobile gadgets in higher education is instant messaging. The ambivalence about instant messaging at African higher educational institutions is possibly explained by: 1). The perceived distractive nature of text-based messages, 2). Limited academic conceptualization of how textual resources can be optimally integrated into mainstream instructional practices and 3). Uncertainties about academic rigor of discussions generated via text messages. Notwithstanding these academic concerns about mobile instant messaging, this social practice (instant messaging) heightens Web 2.0 academic possibilities like subscriptions to information, building of social networks that promotes social interaction and brainstorming, and fostering mutual understandings through sharing of assets like opinions or stories [12]. Mobile Instant Messaging (MIM) enhances fruitful communication among informal learning clusters through the sharing of social objects, learning resources, mutual intentions and learning needs.

Despite the aforementioned academic incentives, what is least understood in mainstream literature is how MIM can promote digital inclusion of learners from diverse academic backgrounds. Therefore, the extent to which MIM can bridge the digital divide particularly, the epistemological divide of learners in resource-poor contexts needs to be explored to ensure equitable communication and balanced academic participation in higher education. Fostering digital inclusion is essential to student meaningful participation in learning environments plagued by unreliable networks, asymmetrical access to networked devices, and where content delivery tends to be institutional context-dependent.

The rationale of this paper, therefore, is twofold: 1). To explore the pedagogical value of an instance of a MIM service, WhatsApp, particularly its capacity to heighten academic participation among all learners, 2). Examine MIM's potential to breach the digital divide among learners in geographically dispersed informal contexts. An informing framework comprising WhatsApp-enabled consultations between an academic and his students, and students and their peers was drawn upon to explore the potential of MIM to promote equitable participation in diverse informal spaces. The rest of

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the paper is structured as follows: a literature review and theoretical framework are articulated, methodology, presentation of findings and discussion are provided, and a conclusion is given.

2. LITERATURE REVIEW

2.1 M-Learning

Mobile learning is one highly contested term that defies precision in its definition due to the ever shifting notions and perspectives on the term. These range from a nomadic (roaming) learner accessing learning resources through the mediation of intelligent mobile gadgets to provision of educational resources via mobile devices and networks. Consistent with the latter perspective, Kukulska-Hulme and Traxler [16] suggest that mobile learning (m-learning) is generally about enabling flexible learning through mobile devices. Similarly, Wood [24] contends that m-learning underscores the appropriation of mobile and information technology devices such as personal digital assistants (PDAs), mobile phones, laptops and tablet PCs for teaching and learning.

However, new constructions of m-learning embrace the mobility of the context of interaction that is mediated by technologies. Centre for Digital Education [5] suggests that a new direction in mobile learning enables mobility for the instructor including creating learning materials on the spot and in the field, using mobile devices with layered software such as Mobl21, Go-Know or Blackboard Mobile Learn. As such, the new notion of m-learning foregrounds a transitory context in which all learning resources (interacting peers, educators, pedagogical content, the enabling technology) are all "on the move". Mobile learning, therefore, potentially breaches the spatial, temporal, and time zones by bringing educational resources at the disposal of the roaming learner in real time. It also lends itself to overcoming the shortfalls of traditional instructional delivery, which often relies on transmission of pre-packaged content, delivered by academics at specific times and venues. Essentially, it grants the learner considerable control of when they want to learn, what to learn and from which location they learn it [1].

2.2 Mobile Instant Messaging

Mobile instant messaging (MIM) is an asynchronous communication tool that works on the wireless, handhelds and desktop devices via the Internet and allows students and peers to chat in real time [7]. Given the high penetration of mobile phones at South African university universities and the concomitant demands for networked engagement at tertiary learning level, MIM presents ideal opportunities for student collaborative learning and fostering of on-task behaviour.

MIM is valued for its capacity to foster unique social presence that is qualitatively and visually distinct from e-mail systems. As Quan-Haase, Cothrel and Wellman [19] suggest, IM applications differ from emails primarily in their focus on the immediate delivery of messages through: 1) A "pop-up" mechanism to display messages the moment they are received; 2) A visible list ("buddy list") of other users, compiled by the user; and 3) A method for indicating when "buddies" are online and available to receive messages. By providing a detail account of the online presence of users (online, offline, a meeting, away), MIM, therefore, provides a rich context for open and transparent communication that recruits focus on the interaction itself and alerts communicants to the temporal and time-span constraints of the interaction. What remains unknown, however, is the influence of social presence in MIM on the digital inclusion of students with varied exposure and experience in academic use of these conversational technologies.

Cameron and Webster [4] conducted a study on the use of instant messaging (IM) by 19 employees from four different organisations. Their findings suggest that critical mass is one of the core explanations for widespread adoption of IM, that is, frequent use of IM was observed in organisations with employees who had surpassed the minimum threshold experience in its academic use. IM also displayed an informal tone, was conceived as appropriate when senders wanted to emphasise the intention of the message, and elicited quick responses and efficient communication (Ibid). Sotillo's [22] study explored fourteen English as Second Language (ESL) learners' negotiation of interaction and collaborative problem solving using IM. The findings suggest that collaborative engagements were critical to addressing some communication breakdowns that arose among learners during their fixing of technical problems of video/audio components of Yahoo IM and synthesis of information from diverse media. The dialogue in an IM environment enhanced learners' awareness of various linguistic forms and grammatical structures of the foreign language. Although this study examined the technology-mediated interactions of students with varied linguistic competences, the study did not interrogate the relationship between MIM and digital inclusion of students.

Other literature have documented the educational benefits of MIM as: Encouraging contact between students and faculty, developing reciprocal interactions and academic cooperation between students, heightening active learning, providing instant feedback, emphasising time on the tasks, communicating high expectations, incorporation of a diversity of talents and affording users some authorised access to academic resources [6, 9, 7]. While these academic incentives constitute useful motivators for the appropriation of MIM for educational purposes, they render little insights into the potential of MIM to transform traditional forms of pedagogical delivery.

3. THEORETICAL MODEL

3.1 The FRAME Model

Koole's [15] proposes a Framework for the Rational Analysis of Mobile Education (FRAME), a conceptual lens for grasping mobile learning that emerges from the convergence of mobile technologies, human learning capacities, and social interaction. The FRAME model conceives the collaborative construction of authentic information in mobile learning contexts to involve the intersection of interactions (between individually, dyads, groups), and the mediating role of conversational technology as shown below (See Figure 1).

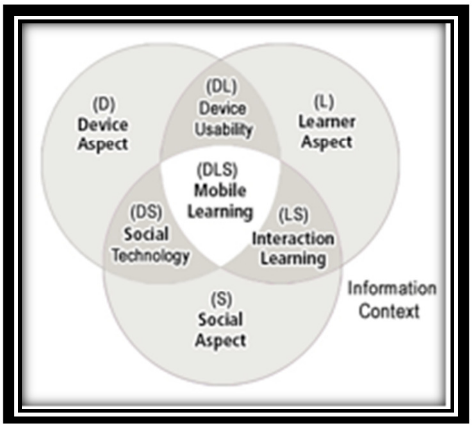

Figure 1: The FRAME Model (Koole, 2009, p. 27)

As shown in the Venn diagram, there are three intersecting circles comprising the technological device (D), the mobile learner (L) and social aspects of the interaction (S). At the intersections of these three variables are issues relating to the usability of the device (DL), instructional and learning theories that activate mediated interaction (LS) and the social aspects of the mediating technology (DS). The heart of these three intersections of three variables (device, learner and social aspects) is the ideal conditions for mobile learning (DLS).

The **device aspect** (D) refers to the physical, technical, and functional characteristics of a mobile device. It is important to assess these characteristics which invariably affect the interface between the mobile *learner* and the *learning task*(s) [15]. The **learner aspect** (L) underscores the cognitive abilities, memory, prior knowledge, emotions, and possible motivations of the individual learner. It emphasises understanding how learners use what they already know and how they encode, store, and transfer information. The mobile learners in a MIM context bring different kinds of knowledge (tacit knowledge, peer-based knowledge, pedagogical content knowledge) and perspectives in their conversations with each other via networked devices. The **social aspect**(S) constitutes the seedbed of interaction and cooperation. Individuals must adhere to the rules of engagement and cooperation which enable them to exchange information, acquire knowledge, and sustain cultural practices.

Koole [15] suggests that **device usability intersection** (DL) draws on considerations from both device aspect functionalities and attributes of the individual or collective of learners. It foregrounds technical aspects of the technology which impact on users' cognitive demands and sense of psychological satisfaction, which affect their cognitive load, ability to access information, and the ability to traverse different physical and virtual locations [15]. Depending on the group size, the object of collaborative interaction, and interactional dynamics in MIM, numerous, interlocking discussion threads via MIM threaten the academic quality of discussions due to increased cognitive load on learners. This may invariably undermine the ability of learners to meaningfully engage with peers and academics.

Social technology intersection (DS) emphasises the capacity of the device to trigger and sustain communication and collaboration amongst *multiple* individuals and systems. Device technical capabilities such as short messaging service (SMS), telephony, and access to the Internet through wireless networks directly influence information exchange and collaboration processes between people with diverse needs, intentions and priorities [15]. The **interaction learning intersection** (LS) synthesises learning and instructional theories and is informed by a social constructivism philosophy [15]. It is located in learners' processes of meaning making through either direct interaction with information-seeking peers or their interpretations of content.

4. RESEARCH QUESTIONS

1. What is the influence of WhatsApp on the academic participation of Third Year Information Systems students at the Central University of Technology?
2. Can the use of WhatsApp gainfully shift pedagogical delivery in informal learning contexts?
3. How can WhatsApp be harnessed to effectively bridge digital exclusion in resource-constrained learning environments?

5. METHODOLOGY

5.1 The Case Study

This study adopted a case study approach. As Fouché and Schurink [10] suggest, case studies help qualitative researchers to immerse themselves in the activities of a small number of people to obtain an intimate familiarity with their social worlds and to look for patterns in the research participants' lives. One of the researchers, an Information Technology lecturer, adopted a MIM application, WhatsApp, as a consultative environment for addressing student queries after lectures. This scaffolding in problem solving was intended to augment the in-class interactions that were constrained by time and lecturers' workloads. The lecturer observed that although students often had several questions to pose to him in class, question-based lecturer-student and peer-based engagements were constrained by several factors. These included limited contact time, perceived transactional distance between himself and students and low self-esteem students' lack of confidence in addressing the lecturer's questions publicly due to fear of potential ridicule by peers and / lecturers. The adoption of an anonymous MIM in lectures and beyond, therefore, was envisaged to liberalise lecturer-student engagement and render a voice to shy and low-self-esteem students.

The case study involved third year Information Technology students undertaking an Information Technology (IT) module at the Central University of Technology (CUT) in South Africa. Given that the rationale of the study was to explore the potential of networked technology (MIM) to foster digital inclusion, a technology-based module provided an ideal context for such an investigation. Therefore, to supplement lectures and the institutional learning management system where pedagogical content (lecture slides, additional readings, course notes, learning tasks) was transmitted, a MIM, WhatsApp, was adopted as a supplementary consultative space through which students engaged with peers and the lecturer in real time as well as asynchronously. The lecturer required students with Web-enabled devices (Smart phones, PDAs, iPhones) to download WhatsApp to their phones and form consultative clusters (discussion groups) comprising 7-10 students per cluster in addition to the lecturer. The 8 clusters comprised a total of 77 students who discussed the questions they generated with their peers in their respective clusters including one question posted by the lecturer to all clusters. Students reserved for lectures the challenging questions they failed to address and the lecturer would render detailed explanations and feedback to the entire class. Intergroup conversations were also encouraged.

Student clusters on WhatsApp served as vital consultative forums for engaging with group members and the lecturer on academic matters. The lecturer informed students on his availability on WhatsApp at any time (between 8 am-10 pm) to address their queries, problems and course related issues. Mindful of academics' dominance of traditional lectures, the lecturer sought to diminish his regulatory authority by maintaining a social presence on WhatsApp and getting involved only upon invitation. To address perceived knowledge and power asymmetries between peers, the lecturer grouped students with varied academic capabilities together and expected them to log on WhatsApp using their phone numbers to ensure the anonymity of intra-cluster and inter-cluster interactions. The lecturer, however, authenticated his presence by using his real name.

5.2 WhatsApp Messenger

WhatsApp messenger is a cross-platform Smartphone messenger that employs users' existing internet data plan to help them stay with their learning community [23]. WhatsApp chat features render visible all the interactants who are online at any given moment, allowing them to randomly consult with their social networks in real time or asynchronously.

Table 1: WhatsApp's collaborative features

Multimedia	Allows users to exchange text messages, videos, images, and voice notes with their interactional network and contacts.
Group chat	Supports the interaction of up to 11 group members / interactants. Members can engage in discussion forums.
Unlimited Messaging	WhatsApp Messenger interactants enjoy abundant messaging without limits. The application uses 3G/EDGE internet data plan or Wi-Fi to ensure continuous data transmissions across platforms.
Cross platform engagements	Interactants with different devices (personal digital assistants, Smart phones, Galaxy tablets) can message one another through various media (text messages, pictures, videos, voice notes).
Offline messaging	Messages transmitted when the device is off or is located outside the network coverage area are automatically saved and are retrievable when the network is restored or when the device is turned on.
Charges involved	Because WhatsApp Messenger uses the same internet data plan used for email and web browsing, there are no costs in intra-communications via WhatsApp. There are no charges even for international calls involving interactants on WhatsApp

(Source: WhatsApp, 2010)

Given the high tariffs regime for mobile calls in South Africa, interactions via WhatsApp are attractive to students as they are free-of-change and allow for convenient communication.

6. RESEARCH METHODS

6.1 Interviews

Fifteen students were interviewed in depth to establish their experiences of using WhatsApp for academic consultations. The interview questions investigated student extent of use of the application, the different contexts of its use, other applications which WhatsApp was used in conjunction with, the various learning communities which students consulted with and the academic benefits of using this application. Questions were also posed on student feelings of psychological empowerment and how their academic participation was affected by their adoption of WhatsApp. The research participants were interviewed in a laboratory foyer, a cosy, convenient space many students were more familiar with than privileged spaces like the lecturer's office. Each interview lasted for about one hour and was recorded using a digital audio recorder to ensure that the data reported were the original, authentic utterances of research participants. The raw data was transcribed in Microsoft Word, printed, sorted and analysed using thematic content analysis injunction with Koole's [15] FRAME model.

6.2 Questionnaires

To corroborate the evidence from interviews on student experiences of WhatsApp, 95 students with WhatsApp-enabled phones were surveyed to investigate their perceptions and perspectives on the academic value of this tool. A semi-structured questionnaire was e-mailed to these learners and 77 of them voluntarily participated in the survey. The questionnaire investigated the pedagogical value of WhatsApp, its functionalities which students conceived as helpful and the dynamics of participation via this messaging service. Students were given the options to e-mail back their responses or to print their responses and drop them into a physical drop box. The responses were analysed using quantitative analysis.

7. DATA ANALYSIS

While thematic content analysis helped us to develop themes from the raw data, it was employed in conjunction with concepts drawn from Koole's [15] FRAME model as shown in Table 2.

Although interviews provided insights into the diverse student academic experiences of WhatsApp, corroborating this evidence with quantitative computations of student perceptions of WhatsApp was necessary to develop a more informed picture of its educational usefulness. A questionnaire based on a Likert scale was designed to determine inter alia the following, the usability and user-friendliness of this application, levels of student participation and collaborative problem solving via WhatsApp, its potential to trigger deep reflection, collaborative creation of knowledge, and its complementation of classroom learning practices.

8. DISCUSSION

WhatsApp's mediation of learning profoundly impacted a majority of students' ability to engage with peers and the lecturer. The adoption of this application for academic purposes scaled up participation in diverse ways. Clearly, it provided an informal, instantaneous and convenient way of exchanging and sharing vital academic information compared to e-mails and hence promoting self-paced learning for students. Many respondents reported that WhatsApp enabled them to "port" their learning resources across different spaces (at home, cafeterias, libraries, on public transport) thus extending the learning time and augmenting the traditional consultation space.

Student engagement with the lecturer and peers' questions and answers also enhanced their mental modelling of the lecturer's general style of questioning in the final examinations, thus recruiting more student interest in the application. The platform also enabled student cognitive scaffolding through group sharing of information and relaxed the pressure of individual problem solving and reflection. The statement: "*I was used to individual problem solving through private study, but now I have learned to value my peers' opinions and to engage with their views and perspectives"* suggests a shift in work ethic from individual accomplishment to collaborative interaction and co-construction of knowledge. As Rambe [20] suggests, the seamless integration of devices and platforms (for example, mobile phone platforms, and texting culture) affords mutual, recursive engagements that potentially impact students' meaningful learning experiences and generate intimate, [academically productive] connections among peers.

Table 2: Device usability intersection

Theme	Category	Examples of interview transcripts	Researchers' comments
Portability	Mobile learning Context-free access	The beauty of WhatsApp is that *it's an application run on a portable mobile device*. I can scroll down and *browse through my peers' questions, queries and comments at any place*. Because messages can be read anywhere, even in restricted areas like banks and hospitals, the application allows for flexible learning. Also I can read stuff from my lounge suite or my bed [Student]	Just-in-time learning is supported through the porting of content anytime, anywhere. The portability of the device upon which the application runs enables flexible learning
Information availability	Information synthesis Bridging information divides Just-in-time learning	When preparing for my final examinations or reading for my assignments, WhatsApp allowed me to pull together diverse ideas and perspectives from peers without the pressure of going to the library to read 300 page volume of texts [student] The convenience of accessing information from one central place enabled me to get just the content needed at any given time. I didn't need to read everything for an assignment [student]	Extraction of ideas and views from an accessible information repository is conceived as more expedient for exam preparation than navigating through voluminous primary texts. WhatsApp enabled just-in-time learning as opposed to just-in-case learning
Psychological comfort	Reducing cognitive load Minimized uncertainty Cognitive scaffolding	WhatsApp questions and answers reduced the huge mental effort to think about the nature of exam questions as these questions probably gave us intelligent guesses about the lecturer's style of questioning in examinations [student] Discussing concepts and problems in groups lifted the burden of individual self reflection and pooling together our collective minds helped us develop diverse perspectives, and understand concepts more clearly [..][student]	WhatsApp afforded a reduction of cognitive load and rendered mental modeling of future academic behavior and engagements Collective intelligence was activated through student collaborative learning in groups.
Visual appeal	User friendliness	I found WhatsApp to be an easily accessible and user-friendly application. This was particularly important for some of us who are less technologically sophisticated. All icons and navigation features are accessible, so they are "cool" [student]	Technological acceptance activated by the visual appeal of the application

(Adapted from Neilsen, 1993, Koole, 2009)

Table 3: The Social Technology intersection

Theme	Category	Examples of interview transcripts	Researchers' comments
Device connectivity	Sustained connectivity Convergence of networks	My Smartphone is WiFi-enabled so I do not need to rely on the often erratic institutional networks to access WhatsApp postings from peers and the lecturer [Student] Some of our lecture rooms have wireless connections so if my Samsung Galaxy tablet's 3G networks or Virtual Private Networks fails to connect, I can quickly switch on to the WiFi enabled classroom network during lectures to refresh my memory on the latest questions asked by peers [Student]	Wireless connectivity complements institutional networks by providing access to content when institutional networks fail. Networked access to content across different spaces and platforms
System connectivity	Limited connectivity	The challenge with WiFi enabled networks through which I access WhatsApp queries and answers is that connectivity tends to be slow. It is different from broadband where access is often instantaneous [student]	Slow connectivity

(Adapted from Shneiderman and Plaisant, 2005; Koole, 2009)

Table 4: Student responses to questionnaires

NATURE OF QUESTION	CATEGORY				
	SA	A	NS	D	SD
I enjoyed the flexibility of WhatsApp online discussion forums compared to classroom face-to face discussion forums.	**21**	**48**	05	03	00
My participation in learning activities on WhatsApp virtual classroom was more effective than in face-to-face lectures	**15**	**42**	01	11	08
Receiving questions from my lecturer and colleagues anytime and anywhere frustrates me because am not given time to rest.	02	08	09	**16**	**42**
WhatsApp online discussion forums facilitate collaborative learning better than face-to-face lectures and tutorials	**19**	**27**	**25**	06	00
My ability to communicate was limited in a classroom compared to WhatsApp online discussion forums.	**29**	**28**	12	02	09
WhatsApp discussion forums allowed me to have more time to reflect deeply before giving my opinions	**42**	**28**	07	00	00
Knowledge creation is higher in WhatsApp online discussion forum than in face-to-face classroom environment.	**27**	**33**	09	03	05
My participation level was higher in WhatsApp discussion forums because the technique promoted layback learning	**41**	**22**	06	07	01
WhatsApp online discussion forums encouraged me to construct knowledge instead of acquiring it passively from the lecturer	**37**	**32**	05	03	00
WhatsApp virtual classroom limited my expression of ideas	00	04	00	**41**	**22**
WhatsApp online discussion forums can supplement face-to-face classroom learning.	**26**	**51**	00	00	00
WhatsApp online discussion was a wastage of time.	00	00	00	**49**	**28**
WhatsApp messaging is cost effective.	**35**	**42**	00	00	00
The opportunity to experiment with new things on-line was possible on WhatsApp	**38**	**38**	00	00	01
I would recommend the online forums for all my courses	**08**	**25**	**15**	**17**	**12**

Key: SA=Strongly Agree A=Agree NS=Not Sure D=Disagree SD=Strongly Disagree

8.1 Bolstering student psychological confidence

Since many students had WhatsApp-enabled phones, discussions via this application broadened the participation base by recruiting and sustaining the critical questioning and information seeking practices of students. This was particularly the case for less confident students who often conceived lectures as intimidating, hegemonic spaces that disrupted transparent and open communication. As some student interviews demonstrated, WhatsApp's anonymous communication potentially bolstered shy students' confidence to contribute online to overcome their general apathy in classrooms. The statement: "*As a shy student, the exciting thing about WhatsApp is the anonymous interactions its gives. My confidence to post questions has improved because I just post questions and nobody ever knows*" bears testimony to this psychological empowerment. Through WhatsApp, therefore, we discerned the increasing metamorphosis of what Jenkins [13] terms a "participatory culture"-a culture with strong support for creating and sharing individual users' creations, where the members feel the efficacy of their individual contributions and personal connections. More so, the digital trails of postings and discussion threads constituted an accessible, user friendly information repository, which many students found more navigable and easier to grasp than voluminous IT textbooks.

8.2 Transactional affinity spaces

Students' affirmative questionnaire responses on the capacity of WhatsApp discussion forums to foster knowledge creation (77.9%), deep reflection (90.9%) and meaningful communication (74%) smack of the potential of this application to foster "affinity spaces." WhatsApp discussion forums perceivably constituted what Gee [11] coins as "affinity spaces," that is, discursive spaces driven by common endeavours to bridge [participation] differences based on demographic considerations (age, class, race, gender, and educational level) and whose participation is often tied to interactants' interests, skills and capabilities. The inductive discovery offered by student critical engagement with lecturer and peers' questions, comments and elaborations helped them to develop mental models on the typical questioning style of the examiner. This constitutes the transfer of learning across different contexts.

8.3 Flexible deliberative spaces

Corroboration of interview data with questionnaire responses yielded similar results. There were 69 participants (90%) who preferred the flexibility and spontaneity of WhatsApp online discussions to pre-packed content and inflexible delivery of traditional classrooms. Survey data suggests that 57 respondents (74%) preferred participating in WhatsApp virtual forums to traditional classroom interaction, while only 19 students (25%) preferred in-class to online discussions. The higher preference of WhatsApp to in-class discussions can be attributed to the anonymity of the online interactions, which potentially democratised participation of shy and less confident students. As Ng'ambi [18] aptly observes, many students find didactic teaching boring because it requires them to learn passively, and tends to create inadvertent barriers to communication between students and teachers. One such psychological barrier is the need for one student to speak aloud while the rest of the class turns around to look at the speaker, a practice that conceivably mutes other voices [18]. To the contrary, the anonymity and affordances for personal reflection rendered by the WhatsApp "virtual learning classroom" potentially democratised communication as they reduced the potential threats of putting academically weak and shy students "on the spot."

8.4 Pedagogical transformation

In their interview responses, students articulated several observations that had implications for transformative pedagogical delivery. Most importantly, many students claimed that WhatsApp created an informal, social constructivist learning environment through which their rigid learning styles were challenged and transformed. For example, students who normally relied on private individual study and averted collaborative engagement eventually found their "lone wolf" [2] mentality subverted by WhatsApp's demands for collaborative problem solving. This engagement model was buttressed by pedagogical design of tasks that demanded student joint problem solving, collaborative engagement with peers' questions and the development of information-driven learning communities.

Transformative learning in informal contexts played out in the emergent student engagement with learning resources and critical thinking. Questionnaire data affirmed that 70 respondents (91%) believed that WhatsApp discussion forums allowed them to reflect "deeply" on questions and queries before giving their opinions. This feeling could be attributed to the fact that these forums mitigated against the pressure of instant, spontaneous responses immanent in question-response-feedback format of lectures. Interviews data also cohered with this finding of the survey. Students claimed that the asynchronous nature of discussions afforded them the time to research, consult widely with peers and think critically before responding.

Since WhatsApp archived all questions and answers, digital trails were created for augmenting students' memory, and enabled student recursive interaction with old and new content organically generated by the lecturer and themselves. These [Web-based] environments, therefore, allowed the integration of prior knowledge with new knowledge, expanded student cognitive skills through their access to prior knowledge, facilitated the identification of key points in the content and helped learners understand the differences and similarities between key points [14].

8.5 Distractive technology

Despite the academic value of WhatsApp, 10 participants (13%) expressed some reservations about receiving learning material 24\7. These participants were predominantly adult learners who had families and therefore conceived after hours as family's quality time. These adults, therefore, were ambivalent about the blurring of the academic and social divide and conceived the mobile application's collapsing of contexts as "anti-social" and disruptive of family life. However, since these adults only constituted a minority of the class surveyed, it was not surprising that 54 respondents (70%) supported the reception of academic material after hours. They indicated that such queries and responses enabled them to revisit and revisualise their lectures and saved them from looking up for materials from libraries and books during late hours. Assuming that this saved time was deployed for other purposes like academic study, it can be envisaged that WhatsApp offered flexible learning. 46 respondents (60%) concurred that receiving learning material anytime promoted collaborative learning since students can access assistance from peers whenever they are studying.

8.6. Digital inclusion

The appropriation of WhatsApp for academic purposes created a networked learning community in which more students were actively involved in constructive engagement with academic material. Anonymous communication afforded by this application broadened the involvement of shy and less confident students who felt previously marginalised by asymmetrical speaking turns in traditional classrooms. Many of these students were Second English Language learners who struggled to articulate themselves in a foreign medium of communication. They, therefore, conceived the use of some street English and "code switching" (switch from English to their vernacular languages) on WhatsApp as accommodative of their linguistic challenges.

In spite of WhatsApp's academic usefulness, contradictions emerged with regard to possibilities for its wide scale implementation across different courses. Although participants unanimously agreed that using it for teaching and learning was not necessarily a wastage of time, only 33 (43%) of them recommended its implementation in all their subjects. The fear of dealing with huge workloads particularly responding to peers' queries, requirements to give critiques based on in-depth academic investigation, including the pressure to work collaboratively, were cited as the main concerns.

9. CONCLUSION

The academic appropriation of WhatsApp afforded the convergence of student individual traits (abilities, skills, and capabilities), situated contexts and the conversational technology, which triggered student meaningful involvement in learning. WhatsApp constituted an alternative learning space for shy, less confident students due to its capacity to promote anonymous, asynchronous collaborative learning. Although anonymity often raises uncertainty about learner's assumption of responsibility for one's perspectives and views, this was controlled by the lecturer's knowledge of all group members as he saved on his phone all the student names against their phone numbers. In contrast, WhatsApp rendered democratic expression through information seeking, content-directed queries, elaboration of concepts and information sharing practices.

Mature adult learners with families, however, expressed ambivalence about WhatsApp's integration of academic and social spaces. This convergence of spaces activated their consciousness of the contradiction between demands for unhindered access to learning resources anytime, anywhere, and competing family commitments after-hours. More so, in spite of the overwhelming support for mobile learning, some students raised their concerns about its wide scale adoption in other courses. We attributed these concerns to the application's substantial demands on collaborative involvement and deep reflections during interactions.

In terms of pedagogical transformation, the deployment of WhatsApp augmented the lecturer-student interactions beyond classrooms and provided alternative social constructivist environments for lecturer-student and peer-based co-construction of knowledge. The role of the lecturer was transformed from that of an instructor to a facilitator, mentor and knowledge consultant who provided guidance as and when it was needed. Student roles were also transformed from that of information receivers to information generators, collaborators, information seekers and givers, critical thinkers and group leaders. A learning community through which knowledge was communally created, manipulated and sometimes contested was created. Students, however, expressed the challenges of slow connectivity via their mobile phones, and WhatsApp's blurring of the divide between academic and social issues.

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Preliminary Findings of an Investigation into the Teacher Expectations of an iPad Pilot

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ABSTRACT
Schools are increasingly investing in technology, yet the challenge is how best to make use of this investment to enhance teaching and learning. Mobile Learning (mLearning) has been made possible with mobile technologies, but little research has been done into this area as it is a recent innovation. This paper will report on the expectations of teachers concerning the introduction of iPads and the required change in pedagogy at a high school that has decided to pilot these iPads in selected junior high classes.

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

General Terms
Human Factors

Keywords
High School Education, Teachers, iPad, mLearning.

1. INTRODUCTION
"Whether one is excited, challenged or terrified by the influx of technology in schools, the fact remains that emerging technologies are increasingly being infused in school cultures and do have a major effect on teaching and learning" [21, p455].

The conceptualization of this statement is being piloted by a private high school in South Africa. The school has initiated this pilot in order to assess whether using the iPad in a teaching and learning context will benefit the learners and teachers at the school. The underlying motivation for the pilot is that the school environment should facilitate students being able to learn through active participation and interaction [22].

The motivation behind choosing the iPad technology for the pilot was based on the lack of success in computing laboratories. The head master at the school felt that the laboratories allowed for instruction of learners, but did not provide learners with an ability to direct and guide their learning. It is felt that the iPads, as mobile devices, have more advantages than laptops in education [13]. The advantages being that mobile technologies are more portable, they make digital reading easier, they have touch screen interfaces, there is a large suite of applications, online textbooks are available and the long battery life makes it ideal for the school day [13].

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The school requested teachers across the high school to volunteer to participate in the pilot for the present academic year. All teachers that volunteered received a free iPad as well as training on the use of the technology. Of a teaching staff of 87, 17 teachers volunteered to take part in the pilot, where the primary mode of teaching and learning is the iPad. Each subject had to be represented to ensure that the iPad would be used for all teaching and learning for the grade. The decision to select the Grade 9 year was based on the scope of subjects taught to this grade, as well as the fact that this is not the first year of high school. The learners in the grade were also requested to volunteer and their parents were required to give consent. The learners that volunteered and were selected had to purchase iPads that were offered at a discounted price. These selected learners were then placed into 2 separate classes and have only been taught with the iPad, however the learners have had access to both printed textbooks and the textbooks on the iPad. The rest of the teachers and learners have continued to use traditional instruction and learning approaches.

The objective of this paper is to report on the expectations of teachers (both those that volunteered and those that did not) concerning the introduction of iPads and the change in pedagogy required, by analysing these expectations using a modified Unified Theory of Acceptance and Use of Technology (UTAUT) model [26]. The constructs of the UTAUT model that have been addressed are performance expectancy, effort expectancy, social influence, facilitating conditions and pedagogical views.

2. THEORETICAL BACKGROUND
Over the years, researchers in Information Systems have developed and used a variety of models to understand the factors affecting the acceptance and adoption of Information Technology. These models include the Theory of Reasoned Action [10, 2], the Technology Acceptance Model (TAM) [8], the Theory of Planned Behaviour (TPB) [1], the Model of PC Utilisation [24], Innovation Diffusion Theory [21, 19] and the UTAUT [26]. For the most part, this research has taken place in organizations and to a lesser extent in higher education institutions. Each model has been developed by extending the previous model(s) with the idea of overcoming the weaknesses in the previous model(s) and/or to integrate the previous model(s) and/or to extend the previous models to account for additional variables [27].

Venkatesh et al [26, p426] suggest that research into the adoption, acceptance and use of technology is "*the most mature research area in contemporary information systems research literature*".

Mobile technology is relatively new and researchers have only recently started investigating its acceptance and use [15, 9]. Advances in mobile technology and wireless networks, together with the availability and affordability of mobile devices have made mobile learning (mLearning) possible [9]. MLearning refers to the benefits that exist with mobile technology that could fundamentally change the approach to teaching and learning, allowing flexibility, engagement and collaboration [17, 14] and can be seen as a way to support learners and complement the existing structure of teaching and learning [16].

So far, research into mLearning has looked at the factors leading to behavioural intention to use mLearning [27, 15, 9], attitudes towards m-learning [5; 16; 11], the impact and uses of mobile devices [13, 17, 12] and the issues faced and benefits perceived [14, 20]. These studies are specific to mLearning, as opposed to eLearning or learning using technology generally.

As the iPad is a new mobile device (released in April 2010 [3]), very few studies into its adoption and/or use in education have taken place. Very little has taken place in secondary schools (most researchers have surveyed university or college students and most work has been quantitative in nature) and none has taken place in a high school in South Africa. The decision to pilot the use of iPads at a South African high school has presented the opportunity to carry out academic research to investigate the expectations of teachers at the start of the iPad pilot.

As iPads are introduced into the classroom, there is a need to study the impact of the technology and investigate how these mobile devices can better support learners through interactive teaching [18, 16, 14]. In addition, research needs to take place on the acceptance and use of mLearning using traditional models [27]. The use of technology at school level could influence the expectations that learners have when they enter tertiary education and/or the workplace [4].

A modified UTAUT model was used to identify the variables that describe the expectations of the teachers. This model helps explain an individual's intention to use and/or the actual usage of technology. The UTAUT model integrates constructs from several acceptance models, so provides a comprehensive base from which to derive the factors to be observed and/or measured.

The UTAUT constructs are as follows [9, 25, 26]:

Performance Expectancy (PE): the degree to which an individual believes that using the system will help him/her achieve gains in job performance. Related constructs are perceived usefulness, motivation, expected outcomes and relative advantage [21, 8, 19, 23, 24].

Effort Expectancy (EE): the degree of ease of use of the system. Related constructs are perceived ease of use and complexity [8, 19, 23].

Social Influence (SI): the degree to which an individual perceives that important others believe he/she should use the system. Related constructs are subjective norm, social factors and image [8, 19, 23].

Facilitating Conditions (FC): the degree to which an individual believes that the infrastructure exists to support the use of the system. Related constructs are perceived behavioural control, contextual constraints and compatibility [1, 19, 23, 25].

Pedagogical View (PV): this "construct" has been included to incorporate the teachers' views of their teaching and the students' learning. Its basis is in performance expectancy and effort expectancy, but a sub-category has been included to differentiate the teaching aspects from other beliefs and perceptions concerning the use of the technology. It includes aspects of self-directed learning: the degree to which an individual increases his/her knowledge using his/her own efforts [7, 25].

Although the UTAUT model has been used in quantitative studies for the most part, the variables have been adapted to this qualitative study due to the size and nature of our potential sample.

3. RESEARCH METHODOLOGY

Our sample respondents are the current Grade 9 teachers at the school. Teachers were categorised into those participating (TP) and those that chose not to participate (TPN). Each of the categories was further divided (randomly) into 2 groups and all 4 groups were interviewed by means of focus group sessions. The motivation for selecting a focus group methodology was due mainly to 2 reasons: firstly, a focus group is able to capture the richness of responses from the teachers, secondly, as the iPad technology is new, it was not possible to determine in advance all the issues that may have arisen. The 4 focus groups were observed and recorded.

The TP category consisted of 5 females (38% of the sample of teachers participating) and 8 males (62% of the sample of teachers participating). The category for TPN consisted of 11 females (65% of the sample of non-participating teachers) and 6 males (35% of the sample of non-participating teachers). The average age of the TP category is 37 years old, while in the TPN category it is 48 years old. The average number of years of teaching experience in the TP category is 16 years while in the TPN category it is 23 years.

The sample constituted 76% of the TP category and 21% of the TPN category. A summary of the demographics is given in Table 1 below.

Table1. The demographics of the focus groups

	TP	TPN
Female	5	11
% of category	38%	65%
Male	8	6
% of category	62%	35%
Average age	37 years	48 years
% of category	76%	21%
Sample size	13	17

The focus group interviews provided rich data for this research. The original constructs from the UTAUT model were used as a starting point for coding the data into themes and Thematic Analysis was used to assist in the identification and analysis of these themes [6].

4. PRELIMINARY FINDINGS

The initial focus group interview sessions have provided interesting responses and comments from the teachers, many of which were not originally expected. The findings are discussed below.

4.1 Teachers That Chose Not To Participate (TPN)

What were your reasons for not volunteering in this pilot?

Teachers raised a number of concerns with regards to the pilot. They felt that the pilot lacked the required infrastructure, in terms of the technology as well as training and staff that could support the teachers. It also contained too much uncertainty and wasn't adequately thought out and planned: "*too much uncertainty, unanswered questions and no contingency plan in place*"; "*no support, no structure, you can't just jump into the iPad implementation*".

The iPad is used to teach across all the 13 subjects in Grade 9. Most of the teachers felt that the syllabus is too large to tackle with a new technology and it would pose a great risk to their teaching and to the learners' academic performance if it wasn't successful: "*the syllabus is too big to spend time fiddling around on an iPad"; "they should have started with 1 subject and then see if it is working"*.

What benefits do you expect that teachers participating in this pilot would gain?

In the focus groups there was a difference of opinions in terms of defining the benefits and the expectations that could be derived from the use of the iPad for teaching. Some of the teachers felt that it could provide learners with new skills and allow for more teacher-learner communication as well as make teachers more efficient: *"teach children how to comprehend new skills"; "allows for instant communication and makes teachers more efficient"*.

Almost all the respondents in focus group 3 felt that the iPad would not bring any benefit to both teachers and learners, as it would require an enormous amount of effort to source and contextualize relevant teaching material. Additionally many felt that it could increase the anxiety amongst teachers due to lack of experience in working with the iPad technology: *"finding teaching material is a big problem, there is a greater amount of effort needed to source material"; "there is an anxiety experienced, not knowing how to work on the iPad"*.

Explain your views regarding the use of the iPad with regards to teaching. How do you expect that the iPad could be used?

As these teachers are not participating in the pilot they were only able to express their perceptions of what teaching with an iPad would be like. From this stance, they were concerned that the iPad would require a different pedagogy from the one previously utilized which would require substantial preparation. They also felt that the need to prepare would result in less teaching time, as teachers try to find their way with this new pedagogy of teaching: *"there will be less teaching going on and no preparation for teachers"*; *"a different form of teaching than we have been trained on"*.

The teachers felt that the iPad could not replace them, the human instructor, but could be used as a support for teaching and not as a replacement: *"the iPad is a good assistant, but cannot replace the teacher"*.

What difficulties or obstacles do you expect, for those participating in the iPad pilot, with regards to teaching?

The teachers conveyed their feelings very emphatically that discipline of learners during the class time would be an issue: *"with the iPad there is an issue of discipline as children can play games and we can't know if they are working"*; "*the kids will need to be policed as they can do other activities on the iPad other than work"*.

Teachers also felt that learners will take less responsibility for their work because of the iPad and not become more self-directed as is one of the main intentions of the pilot: *"if students lose their data the onus is on the teacher to help them get it back"*.

The iPad may also assist students in being dishonest by either pretending to work in class or by copying each other's work, as it is more readily available: *"a child can cheat by directly copying and pasting"*.

Do you find it difficult to use new technology in the classroom?

Only 1 respondent in both of the focus group sessions admitted that technology is a challenge for teaching and feels that the iPad is just a fad which will soon be replaced by some other type of technology. The rest of the teachers interviewed felt they would be excited and comfortable to use an iPad: *"excited to use an iPad"; "I'm comfortable using it"*.

The teachers did not feel that their non-volunteering for the pilot was influenced by their feelings towards technology adoption, but rather due to the structure and implementation of the pilot. The subject taught also influenced their willingness, as certain subjects would be difficult to teach with the iPad due to various factors: "*it is difficult to use for a language"; "technology does not support the subject being taught"*.

Did you expect it to be difficult to integrate the subject material with the technology?

The respondents in one of the focus group interviews all nodded in affirmative agreement with this question. Many of the teachers felt that they would need to spend a lot of time looking for appropriate applications to teach their subjects, which would impact on the content covered during class periods: *"time is a major issue"*.

Some teachers also felt that there are not many applications to be found: *"not many apps and don't know where, when or how to download them"; "for my subject it is difficult to use as there are no applications available"; "there is a clear mismatch between content and the subject on the iPad"*.

Do you believe that your non-participation in this pilot places you at a disadvantage?

More than half of the respondents in these 2 focus groups did not feel that they are disadvantaged as a result of not participating in the iPad pilot. One respondent felt that an assessment of this could only be given once the pilot is well into implementation.

What aspects of the present study would you change?

All the respondents in these 2 focus groups felt that the pilot should be changed in order to improve its chance of success. Many suggested that the school investigate the infrastructure needed to implement a pilot of this nature: "*do some more research into the infrastructure"; "put technology and infrastructure in first"*.

In terms of content and teaching materials available, the respondents felt that the school should invest in more training, not just on the technology, but specific to the subject materials being taught: *"there is no format of a lesson, there needs to be more training, not so much training around the technology, but more around teaching"*.

Given another opportunity to participate in an iPad pilot would you volunteer?

Most of the respondents felt that technology in the classroom is essential to teach this generation of learners. They would be keen to participate in a mobile implementation only if there was adequate infrastructure, support and training available: *"it would depend on resources available"; "with proper training I would participate"*. Only 1 respondent would not be willing to participate in the future and this could be linked to dislike of change and fear in adopting new technology.

4.2 Teachers Participating (TP)

What motivated you to volunteer?

The majority of the respondents perceive a need to introduce technology into teaching and learning due to its pervasiveness*:* *"technology shows potential value"; "believe IT is the way forward"; "believe it will be effective"*.

This category of teachers is also enthusiastic about technology use and motivated to change their teaching pedagogy: *"loves innovation in teaching";* "*loves technology and looks for new ways to make lessons interesting*"; "*it feels good being the first where this technology is used*".

What benefits did you expect to gain from participating in this iPad pilot?

Most expected better communication amongst teachers and learners: "*students can be emailed and email all the time*"; "*it provides better communication*", as well as the ability to use the iPad for interactive engagement of the learner in the classroom: "*it allows the world to come to the classroom"; "allows exploration for learning*".

Respondents in focus group 1 were less positive: *"believe educators don't benefit as they can use a computer and PowerPoint"; "iPads are not window based and therefore can't project"; "feel the laptop is better"*. In addition a concern was expressed about the learners becoming used to using iPads all the time: *"will they cope in an exam? Will they finish in time?"*

How did you expect that the iPad could be used for teaching?

It was felt that the iPad would make teaching more exciting, however, due to the nature of some subjects, there is: *"no need for an iPad";* this is an example given by a Visual Arts teacher where the work is all practical. Others believed that the iPad would provide additional visual material in the classrooms, so: *"dissections can be done on the iPad"*.

Not having to carry books or worry about plug points were mentioned as creating new ways of "movement" in classes.

What difficulties or obstacles did you expect to encounter when using the iPad for teaching?

Besides the problem of learners not paying attention, the teachers didn't expect too many difficulties, as they imagined the iPad to be: *"an extension of a laptop"*. However, they have subsequently experienced infrastructure and connectivity issues. In addition, suitable applications are a problem: *"apps are western based"; "creating a new type of teaching is harder"; "there aren't enough suitable apps"*.

Do you find it easy to use new technology? Explain why you think so.

The general feeling was that it isn't difficult to use the iPad as they: *"are fairly easy to use"*. However, there was a powerful response concerning the difficulty with applications in certain subjects: *"it is time consuming finding apps"*; *"there are no apps"*; *"apps are either too basic or at too high a level"*. Language teaching (apart from English) appears to be particularly difficult. Some teachers are falling back to using their old material and methods (mostly laptops and PowerPoint) and only using the iPad for research.

How did you expect the learners to use the iPad both inside and outside the classroom?

The expectation was that learners would use the iPad for research, note taking and presentations in class, but would be playing games elsewhere. The reality is that students appear to be doing all of these both in and out of class. In addition, email communication between learners and between learners and teachers has increased: *"there is a lot of communication"*; *"students email what they are not sure of"; "hard workers are emailing teachers all the time"*. Teachers' responses to this were mixed: *"I don't mind"*; *"I don't answer email on weekends"*; *"I will respond immediately if it's an easy question"*. The general feeling in focus group 4 was that this wasn't a problem because the sample is small: *"we are excited as they are engaging with the technology"*. However, there was acknowledgement that: *"over time when more students use it, having your own space will be difficult"*.

A negative from focus group 1 was that the extent of the connectivity issues was not expected and it: *"doesn't make sense to teach outside where I get WiFi access"* so the teacher takes the class to the computer lab.

Did you expect it to be difficult to integrate the subject material with the technology?

While some respondents said yes, others felt the difficulties were due to the nature of the subject being taught, the way in which the iPad is used and the availability of applications: "*depends on purpose"*; *"all lessons are different"*.

Generally focus group 1 was quite negative: *"don't plan my classes around the iPad"*; *"iPads are down most of the time and therefore are unreliable"*; *"students complain of limitations and so don't do all the work*". Focus group 4 was more positive, but they thought the learners: *"would be more excited"; "excitement levels dropped as they didn't anticipate using it so much for studying"*.

Focus group 4 also felt that the iPad creates an extra layer between the material and the learner: *"it's not a direct hands-on approach"*; *"there is further distancing of information"*; *"some apps are just videos of people teaching"*.

What differences did you expect to find, with regard to your role, in the classroom?

The expectation was that learners would *"become more independent"* and the role of the teacher would change: *"the learners would find information instead of me giving it to them"; "it changes the way it was done before"*.

A couple of respondents in focus group 1 feel they don't know what they are doing and waste the lesson trying to fix this. Others in that focus group felt: *"this is a great learning experience as I get help from the learners"*.

As *"learners get carried away with games"*, the teachers have had to become more aware of what happens in the class, leading to both positive and negative outcomes: *"the teachers need to make the lessons lively"*; *"I feel I am doing more checking up than teaching"; "it has made me nasty as I have to reprimand all the time"*.

Do you believe that your participation in this pilot gives you an advantage?

Most respondents felt they are at an advantage, but others felt that: *"they don't have as much time as other teachers"*; *"you have to teach the learners how to use an app, then teach the lesson"; "it is very challenging"*; *"teachers who aren't in the pilot want us to teach them"*.

Some teachers were coerced into participating, in order to ensure all subjects were taught using the iPad, but most were keen.

What aspects of the present study would you change?

The strongest response in both focus groups was that the pilot should not have been rolled out all at once: *"took on more than* *we should have"*; *"should have started as 1 lesson a week"*; *"should have been 1 subject a term"*; *"transition phase was not long enough"*.

Other improvements suggested were *"a faster internet line"*; *"more training"*; *"better planning"*; *"they should make a workbook to help the teachers"*.

Focus group 1 teachers were concerned that these Grade 9s would not be ready for the following year and most felt that the iPads should rather be introduced in Grade 8.

4.3 Preliminary Analysis of Responses

The questions posed in the focus group interviews were based on the constructs from the UTAUT model. A broad early analysis of the teachers' responses suggests the following:

Performance Expectancy is the construct that deals with the degree to which an individual believes that using the system will help him/her perform better in his/her job. Most teachers, in both the TP and TPN groups, perceive the iPad to be a technology that can be useful and advantageous to both teachers and learners. However, motivation to use the iPads appears to be lacking. Expected outcomes ranged from teachers feeling that the iPad could enhance the teaching material that they are able to provide for learners, to better communication between teachers and learners. The TP group felt that their use of the iPad in the pilot would provide them with relative advantage, as the adoption of this technology in schools is inevitable in the future. These findings are largely consistent with previous research, which has found that usefulness and relative advantage can be important predictors in determining usage of technology [26, 8, 23]. However, the construct of motivation has shown some deviation from previous research [26].

Effort Expectancy is concerned with the degree to which an individual believes a system will be easy to use. Most of the teachers, in both the TP and TPN groups, did not believe that using an iPad would be difficult. However, some teachers are having problems applying this in the classroom with regards to the transfer of current subject specific teaching skills to the new technology. The teachers do not perceive iPad usage to be difficult, but they expect that the change from traditional teaching methods to teaching with an iPad to be more complex. The expectation that the technology will be easy to use suggests that the teachers will be inclined to use the technology. This is consistent with previous research [8, 19, 23, 26].

Social Influence deals with the degree to which an individual perceives that others believe he/she should use the system. This did not come across as a major reason for participating in the pilot, reinforced by the fact that many are returning to older methods. Previous research has been divided as to whether this construct is influential. The findings in this research are consistent with Davis [8] suggesting that social influence is not a factor in the acceptance of new technology. Previous research has found that this construct is affected by whether or not the individual has volunteered to use the technology [8, 19, 23], such as in the case of the TP teachers.

Facilitating Conditions is the construct that deals with the degree to which an individual believes that the infrastructure is in place to support the use of the system. This seems to be the major factor in the expectations and use of the iPad thus far, resulting in many negative comments around the issues of infrastructure, availability and suitability of applications, planning of the pilot and iPad training. Contextual constraints, related to training on subject specific skills, application and wireless availability at the school, are perceived to be crucial by both groups of teachers, to the lack of iPad adoption at the school. Compatibility issues, with regards to the fit of the iPad technology for certain subjects, and the lack of South African applications have resulted in negative perceptions of the pilot by the teachers. Facilitating conditions are important predictors of acceptance of technology and may be a barrier to usage if these conditions are not seen to be satisfactory [14]. This has been shown in previous research [1, 19, 23], as well as in the present research.

Pedagogical View refers to the teachers' views of their teaching and the resulting learning by the learners. Although previous research has indicated a positive relationship with teachers' attitudes and views towards technology [25] and those of learners, there was a mixed response to this construct in this study. Some teachers have embraced the iPad technology and are using it to enhance their teaching by providing exciting innovation in the classroom. At the other extreme, even those teachers that were excited have become disillusioned, possibly due to the negative facilitating conditions.

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 [8, 19, 23]. These have not been investigated in the current study. Previous research has looked at acceptance and adoption of technology [8, 19, 23, 26], whereas the current research has been investigating the expectations of a new technology.

5. CONCLUSION

The piloting of iPads for all the subjects in Grade 9 classes has been a big change for the teachers and learners in this school. The initial expectation of the researchers was that the non-participating category of teachers (TPN) would be negative, while those that volunteered to participate (TP) would be positive. However, the responses of the teachers in both categories have been mixed; several participating teachers are resorting to their old methods of teaching or are using the iPads to a lesser extent, while some of the non-participating teachers would be willing to participate if given the opportunity now. Many teachers are excited by the opportunities that are being created by the new technology, the ability to change the classroom experience and the enhancement of learning for themselves and the learners. This excitement is being tempered by the lack of applications, an unreliable infrastructure and the pressures of time both within and out of the classroom. The preliminary findings of this investigation are largely consistent with previous research on adoption and acceptance of technology.

Change is always difficult, or at the very least challenging. The implementation of the change is often the crucial component that can determine its success or failure. An initial recommendation to the school would be to stop the pilot to allow for more time for training, sourcing of suitable applications and resolution of infrastructure problems. The next phase could be to reintroduce the iPads in a more phased approach.

The research into this iPad pilot was started quite recently and is a work-in-progress. Various other methods of data collection have recently taken place, namely: surveys that a wider group of teachers has completed, surveys that parents have completed and focus group interview sessions that have taken place with learners that are participating in the pilot study, those that are not participating and those that wanted to participate, but were not selected. The next stage of this research will be to extend the investigation by carrying out further analysis on these other methods of data collection.

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Developing the South African Business Process Analyst: Addressing the Challenges through a new University Programme

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ABSTRACT

The increase in adoption of business process management (BPM) and service-oriented architecture (SOA) has created a high demand for qualified professionals with a diversity of skills. According to Gartner by 2014 there will be a growing emphasis on process-related skills and competencies. However, despite the growing amount of literature available on BPM, little research has been conducted around developing BPM professionals. The purpose of this paper is to provide an analysis of the challenges in developing the business process analyst role. The new business process analyst role that has emerged from the business analyst role is seen as indispensable to the success of BPM and SOA projects.

This qualitative research comprised the initial diagnosing phase of an action research cycle. Firstly in diagnosing the situation in South Africa, interviews with industry players was performed; secondly, a current programme at the University of Cape Town is described and how this programme is attempting to resolve the situation described. Finally, the remaining challenges for higher education are described. The findings demonstrate that BPM awareness, resource definition, BPM education, hands-on BPA experience and availability of skills are amongst the challenges facing the establishment of the business process analyst role in the South African market.

Categories and Subject Descriptors

H.0 [**Information Systems**]: General.

General Terms

Management, Human Factors

Keywords

Business process, BPM, IS curriculum.

1. INTRODUCTION

Business Process Management (BPM), a management practice, and service oriented architecture (SOA), an IT practice, share the goals of improving the agility in their respective areas, and are thus often depicted as going hand-in-hand. BPM provides a use case for SOA that can be understood by the business, whereas SOA provides the necessary agility and flexibility that is not available to BPM from non-SOA-enabled proprietary BPM tools [15, 16, 21].

The interest in BPM is rising; with one study citing 27 per cent of South African companies (all sectors and regions) committing to BPM projects [18] and 71 per cent of respondents in a global Forrester survey reported usage or usage intent of SOA [17]. However, regardless of the promising views offered by implementing both BPM and SOA approaches, numerous challenges persist [1]. One challenge is the high demand for qualified professionals with skills in both SOA and BPM domains [2, 3, 40, 42]. Several Chief Information Officers (CIOs) are concerned that their organisations lack the skill sets and competencies necessary to implement SOA, and that transforming the current information technology (IT) employees is not a swift process [11]. The business process analyst (BPA) role has emerged in this space and has been tasked with supporting a holistic view of business processes and delivering the ability to transform the organisation swiftly [2, 23].

Hence, the purpose of this research is twofold. Firstly, to contribute to research in BPM and SOA by investigating the required challenges to developing the business process analyst (BPA) in South Africa and secondly, to review an existing University course and assess how it is attempting to addresses these challenges.

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2. THE BPA IN SOUTH AFRICA

The Bytes Technology Group identified that amongst the top ten IT skills required; there is a need for more BPAs [12]. The shortage of IT skills is a global phenomenon but its impact in South Africa is substantial and has been problematised in a number of articles [12, 20, 25, 27]. South African organisations are concerned with the small number of people who have a generic understanding of business [12]. Although the South African government has announced that it will allow immigrants with special skills to work in the country, the global skills shortage is seriously affecting the South African market [22].

3. METHOD

This research employs an interpretive epistemology and qualitative research method [7, 41]. The Research comprises two parts. The first part analyses the current challenges experienced by industry in establishing the BPA role. BPM is regarded as an applied discipline and therefore practitioners' viewpoints and opinions are considered of high importance [40]. The second part describes a BPM course and identifies its role in addressing these challenges. There has been an increased call to make Information Systems research more practical and relevant [8] and AR is one way to achieve this [7]. Essentially, action research is a two stage process. The first stage is the diagnosis phase whereby a collaborative analysis of the social situation is undertaken by the researcher together with the subjects of the research. This research forms part of this diagnosis phase.

3.1 Initial Data Collection

A purposive sampling technique was used to identify BPA experts or managers of BPAs from various industry sectors such as banking, retail and insurance across South Africa. The researcher obtained approval from the University's ethics committee prior to contacting the organisation and participants. Interview guidelines were distributed to respondents prior to the semi-structured face-to-face interviews. For candidates who were not geographically close, telephonic interviews were conducted through Skype. Telephonic interviews are accepted as appropriate and useful for data collection [25]. Ten participants from five different organisations were interviewed with one participant being an independent contractor. Table 1 provides the list of participants with their demographics. Four of the five organisations implemented BPM and SOA and one organisation was in the process of implementing them. Two of the participants from the retail industry were in an IT domain and looking after ERP business processes. Data analysis commenced with the transcribing of interview recordings and was followed by thematic analysis [5].

Table 1: Demographics of Participants

Expert	Job Description	Industry	IT /Business Experience
Int1	Senior BPM consultant	Insurance Industry	+ 15 years business
Int2	Senior Business Process Analyst	Petroleum Industry	10 years business
Int3	Senior Business Process Engineer	Banking Sector	8 years business
Int4	Business Process Analyst	Banking Sector	2 years business
Int5	Business Process Engineer	Banking Sector	7 years business
Int6	Former Senior Business Process Analyst	Private	6 years business + 6 IT
Int7	Business Process Analyst	Retail Industry	5 years business
Int8	Business Process Analyst	Retail Industry	12 years IT
Int9	Business Process Manager	Retail Industry	9 years IT
Int10	Business Manager & Process Analysis	Financial Institution	+ 20 years IT & business

4. DISCUSSION OF CHALLENGES DIAGNOSED

The first objective of this research was to understand the challenges in establishing the BPA role. Literature identified two dominant challenges, skills shortages both locally and globally, and ill-defined job titles. The themes emerging from the analysis confirm these, however, participants expressed other challenges they were faced with.

4.1 Job Definitions

According to Hammer [13] organisations needs to define BPM jobs more broadly and increase training to support those jobs. BPM roles were not defined properly:

> *"I am not sure if in most organisation is properly defined what is the purpose of a business process analyst" (Int4).*

> *"Business process analysts are sometimes classified under business analyst, misusing of the term" (Int3).*

> *"You know when you work as a consultant you get an overview of everything but like here [referring to the organisation with frustration] if you are a business process analyst, they thought of you as a PA (Personal Assistance), you are just mapping processes" (Int4).*

4.2 Availability of skills

All participants raised the concern that it is extremely hard to find BPAs and that the current demand would increase:

> *"I think the demand for this skill is going to become more prevalent" (Int1).*

Lack of BPAs is not only a challenge but finding experienced candidates contributes to the challenge. At the time of the interviews some organisations were finding the process of recruiting BPAs challenging.

> *"It is a bit of a challenge to find the right fit for the organisation" (Int7).*
>
> *"You can go through 10 people but not find the right candidates" (Int9).*

> *"so there has been post that has been advertised and taken off because they can't find suitable candidates" (Int7).*

BPAs were being approached by employment agencies:

> *"there are agencies who keep on calling us for opportunities in other financial institutions" (Int5).*

Some organisations are outsourcing to short term employment. This increases the training burden and when the employment contract comes to an end, the BPA leaves with the organisation's knowledge of business processes.

"we will have a person coming in our organisation for four months then leave and another person comes and also leaves for four months. So there isn't that continuity, we constantly train our people…. don't have resources for permanent staff and have been using contractors quiet a lot" (Int9).

It is seen as risky for organisations to outsource the BPA role due to the sensitivity of their activities and knowledge about the business gained [10] and hence, the BPA role should to be a permanent employee of the organisation with an in depth knowledge of processes, systems and business functions.

Lack of finding candidates with experience to apply mathematical and statistical knowledge, was having major implications on the business processes.

"right now we just change processes we don't go back and measure what savings we are doing. Shortage of skills and experience is a challenge" (Int5).

"we are battling to find people especial in South Africa that has Six Sigma training (Int1).

4.3 BPM Education and training

A new theme that emerged was the general lack of BPM education and training. Most of the BPA participants had degrees, while some employers consider a degree a criteria for employment, some respondents felt that a degree is not necessarily a prerequisite.

"having a degree is an easy measurable thing" (Int1).

"I would not say the prerequisite is a degree, because you might get the same knowledge from the degree that you get from a business analysis course. I think a degree is a good way to have but would not make it a prerequisite" (Int1).

For a BPA the important aspect stressed was process understanding, and for that understanding there did not appear to be one sole degree offering:

"understanding how things fit together, which could be anything from a science degree into a marketing diploma" (Int6).

An understanding of how things fit together could be acquired from working as a BPA and attending training on methodologies. According to Topi et al. [35], a BPM course prepares students with an understanding of how to manage business process which is incorporated with understanding of how that strategy is linked to the processes and defined, analysis of processes and consideration of the IT in the process design. Some participants concurred:

"some training will be required to help them understand some principles behind object oriented methods" (Int6).

"as long as they get that way of thinking from their training it's very easy for them to learn the tools and to use the set of tools for BPM" (Int6).

Some participants working with ERP systems felt that skills in ERP were lacking:

"it is quite challenging to find people who have that understanding of how to use PeopleSoft" (Int9).

Furthermore some of the training mentioned by participants included training on modelling tools and modelling in BPMN.

"the technical training on what the tools are and how to use them like BPMN they need that kind of training" (Int6).

One approach is to retrain BAs into a BPAs but this also comes with challenges.

"We are trying to entrench the process thinking to our IT BAs" (Int10).

"There are lot of people coming from the IT and think they know how to interface with the business side of things. If you were a BA or systems analyst doesn't make you a business process analyst because you need to look at the business side of things" (Int2).

Referring to this challenge, Tucci [36] commented that IT people have the ability to fill this role but are not naturals for the job. Finding a balance between the right brain and left brain is very difficult [19] and this presents a further challenge which was referred to by respondents. The mathematical and statistical competency requires logic (left brain) thinking, whereas, the client thinking competency requires right brain, emotional considerations.

"the view of process dynamics and client experience dynamics is such new, people don't necessary think in both dimensions simultaneously" (Int1).

While it was acknowledged that both education and training were lacking, some of the issues concerning training versus education relate to a poor understanding of the BPM area. According to Dixon and Jones [9] the development of BPM management disciplines should be given a higher priority than technological or tool selection concerns. Management disciplines are the domain of tertiary institutions and this has implications on the education that is given to the BPA. Still, the lack of a common vision and definition of BPM among researchers and practitioners is hindering the development of a consistent BPM body of knowledge that can be used for education by both professional certification bodies and universities around the world [6]. Universities have been criticised for delaying the implementation of BPM into the curriculum. Interviewee three also felt that South African educational institutions are also lacking in this:

"I don't think it is introduced at tertiary level and many organisations are very ignorant on BPM, so it's not that well communicated" (Int3).

4.4 Hands-on BPA Experience

According to Hammer [13], knowledge about the organisation is accumulated over the years by working in a particular organisation and cannot be learned from a university. The seniority of this role requires proven experience which is lacking:

"If the organisation wants good business process analysts they need to be think intellectually when it comes to qualifications and hire people who've got proven experience"(Int6).

"the best training for a BPA is experience. As long as they have training that will give them the kind of skills of seeing the bigger picture. The best training is hands on training and working and with people learning from people who have done it before" (Int6).

"most businesses expect that there some qualification or course in Business Process Analysis that can be done and once you have that qualification you are a good business process analysts, it doesn't work that way" (Int6).

4.5 BPM awareness and sponsorship

The state of BPM in South Africa is said to be misunderstood [18]. A lack of BPM awareness impacts on the organisation moving forward with their BPM initiatives. BPM is still perceived as either an academic theory or technological.

"BPM is still much very much of an academic, a theoretical area. In terms of do I find a practical use of it? It is still vague" (Int9).

A related challenge is the lack of BPM sponsorship within the organisation. Interviewee five expressed that the BPM champion who was driving the BPM left, leaving the BPM implementation to fall into cracks as no one picked it up.

"What happen is that the person who was responsible for BPM, reporting to the CEO left. And when he left there was no focus on BPM" (Int5).

"The biggest challenge is getting buy in from the organisations, getting them to understand that they need to invest in this type of skill in the first place. That business process analyst is required to get into the strategic objectives of the organisation so that it does get the sponsorship it needs so that's the first challenge" (Int6)

Without sufficient BPM support, there is little point in appointing BPAs.

"If they don't see the need for BPM at all and are not committed to it, they just waste their time hiring anybody (Int6).

4.6 The Impact of Challenges on the BPA Role

The findings identified five challenges such as BPM awareness BPM education and training, hands-on BPA experience, job definitions and availability of skills (Figure 1). All these five challenges can have an effect on establishing the business process analyst role. Lack of BPM education and training appears to be the dominant theme as it can have an effect on the growth and development of skills, which will impact the performance of this role. However, without BPM awareness there is little point in establishing the BPA role. Overall, there exist many challenges which if resolved would improve the BPA profession.

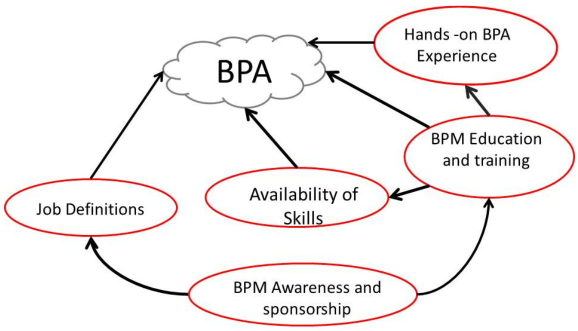

Figure 1: A Framework of Business Process Analyst challenges

5. THE BPM PROGRAMME AT UCT

The BPM Honours programme is offered over two years part time for students already in the market place and comprises two courses. The BPM course is offered in the first year and exposes students to, and to encourage them to apply the principles and practices of Business Process Management (BPM), Enterprise Systems and Business Process Integration to BPM projects. In the second year students perform research as part of a research course. The research course gives candidates exposure to conducting research in a rigorous manner and producing a sound academic technical report (mini thesis). The programme started in 2009 and the second cohort graduated in December 2011.

The BPM course covers enterprise systems, strategic ICT management and Business process management (BPM). Students are exposed to ERP software and software tools used in business process modelling and business process integration. Students are coached in business and academic writing, giving presentations, group work and reviewing literature and have to apply their skills and knowledge to real business cases [37]. The dominant assignment in the BPM course is a work assignment. Students need to select and analyse an existing business process in an organisation. The deliverable document follows the BPTrends business process methodology [14] and includes a scoping diagram, stakeholder analysis and a business case. The analysis phase takes the form of an As-Is diagram and the design phase, a To-Be diagram. Process improvements need to be detailed and metrics determined to ensure that the improvements are realized after implementation. Thereafter an ERP system is selected and activity worksheets detailing the process steps, organizational data, master data and reports need to be produced.

6. THE ROLE OF THE BPM PROGRAMME IN ADDRESSING CHALLENGES

In this section of the paper, the role of the BPM programme in addressing the five challenges is discussed.

6.1 Job Definitions

One of the challenges in this space is the lack of a coherent and agreed description of the roles and responsibilities for the BPA [3, 4, 39]. Prior research in this space has been focussed on the technological aspects and little effort has been devoted to the personnel aspect [28]. There have been some recent studies focusing on the requisite skills. Olding and Hill [26] list a combination of advanced technical skills; in-depth understanding of the business and strong interpersonal skills. In addition, Antonucci and Goeke [3] surveyed the Association of Business Process Management Professionals (ABPMP) and produced a list of the 7 core responsibilities of a BPA. In 2011, a student on the UCT BPM programme researched and proposed BPA competencies for the South African market. This is the most recent and most holistic attempt at addressing this challenge [33]. The competencies are shown in Figure 2 [33].

Figure 2: A Framework for Business Process Analyst Competencies [33]

6.2 Hands-on BPA experience

There are multiple aspects to learning BPM systems: namely, theory and methods must be learnt from both a business and technical perspective, combined with a practical component that integrates the business and technical theory [29]. Involvement of business in the teaching process needs to be increased [34, 38]. In the BPM course, students obtained hands-on BPA experience by performing duties typically required by a BPA in a real-life situation as part of a work assignment. The work assignment created a structure for the requirements for effective learning such as Klahr and Simon's five learning components:

time, active engagement, mental representations, self-explanations and externalizing thoughts [30]. Students documented their learnings and these were classified. Stakeholder collaboration and business process knowledge and skills were the dominant learnings, closely followed by technical knowledge, team dynamics, and project management.

6.3 BPM Education and Training and Availability of skills

The development of the new information systems (IS) curriculum has been partly attributed to emerging fields such as BPM [35]. Prior to that, there was little curriculum support for teaching business processes and the term business process was not listed as a course concept or included as a graduate capability in the Computing Curriculum [32]. The IS 2010 curriculum [35] now lists the BPA as a career track and BPM as an elective course, recommending that BPM content should have significant coverage in the curriculum for Business Analysts (BAs) and BPAs alike. This large shift has left academics grappling to develop courses. BPM courses in higher education are therefore rare and are faced with many challenges [31].

This BPM programme is seen as part of this solution as in two years IT workers are transformed into BPAs without leaving their employ and taking significant time off work. Of the 23 students in the 2011 cohort, 43% entered the programme as developers; 29% as BAs and 19% as team leaders or project managers. Comments of students from their end of year BPM course evaluation include the following:

> *"Business Process Management was very useful and I am now applying it daily"; "BPMN - hugely useful for me"; "Beyond the curriculum: BPM/BPI requires holistic approach."*

This is however a short-term solution and undergraduate programmes in BPM are required. Two students in the research course are currently researching the required curriculum for this purpose.

6.4 BPM Awareness and Sponsorship

The BPM awareness this course contributes to is threefold. Firstly, the graduates of this course create BPM awareness within their organisations. The nature of this programme is transformational as a requirement of a BPA is to be the driver and promoter of BPM within organisations. Graduates of this programme enter the workplace as BPM ambassadors. Secondly, students in this programme often choose to research BPM concerns. As this research is then published BPM awareness is increased. Finally, presenting these findings at conferences and particularly conferences for IT educators should increase the awareness of BPM and maybe encourage more Universities to deliver courses in the BPM space.

7. CONCLUSION

The purpose of this research was to contribute to the BPM and SOA body of knowledge by firstly analysing the challenges in establishing the business process analyst role and secondly describing a course which is attempting to resolve some of these challenges. The dominant challenges in establishing the business process analyst role in the South African include the lack of BPM awareness, poor resource definition, inadequate BPM education, lack of hands-on BPA experience and insufficient availability of skills. Here, Higher education and in particular Information Systems Departments have a role to play. The Honours programme at the University of Cape Town is attempting to address some of these challenges but this paper motivates for more research and more involvement of other institutions.

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Foundational Concepts for Understanding Software Design Patterns

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ABSTRACT
Software design patterns are difficult to learn and teach. From our experience of teaching design patterns, we found students ill-prepared in the prerequisite object-oriented concepts. We have therefore made a study of the building blocks, or what we call foundational concepts, of design patterns. We provide an analysis of one design pattern to show the process in determining its foundational concepts, and then give a table of a number of design patterns selected from those described by Gamma et al., listing the foundational concepts involved in each. We argue that this process has value for lecturers teaching design patterns, as well as for students learning them.

Categories and Subject Descriptors
D.1.5 [**PROGRAMMING TECHNIQUES: Object-oriented Programming**]

General Terms
Design

Keywords
Object-oriented programming, object-oriented design, design patterns

1. INTRODUCTION
Software design patterns (hereafter called design patterns) describe tried and tested solutions for recurring problems of object-oriented design [2]. The application of such design patterns promotes flexibility and reusability in software [10]. The word 'design' refers to the overall structure of a solution. Since the context is object-oriented (OO) programming problems, a design describes the roles of various classes and the relationships between them that should be included in the solution. The word 'pattern' implies that the essence of the solution is described in an abstract way, so that it can be adapted and applied in innumerable ways to solve similar problems.

Design patterns have become an important part of the OO programming curriculum in Computer Science at most universities. Astrachan et al [1] describe design patterns as an essential programming and pedagogical tool; essential for the successful adoption of OO techniques in academic Computer Science programmes. Sterkin [9] also recommends the inclusion of design patterns in academic programmes because they introduce abstractions in software, which are necessary in building complex software systems.

The complexity and abstract nature of design patterns is borne out by the experience of many students and lecturers, namely that design patterns are far from easy to learn and teach. Weiss [11] states that even experienced programmers find it difficult to learn design patterns and this difficulty is much greater for students. Pillay [7] quotes a number of authors that attest to the difficulty that educators find in teaching design patterns, and of students trying to learn and understand them.

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Our own experience also indicates that students struggle to grasp the intricacies of many design patterns, which involves more complex and abstract ideas than introductory OO programming. Although we consider ourselves to have been fairly proficient in design patterns, we were not explicitly aware of the foundational concepts leading to this proficiency. As a consequence, we did not teach many of them explicitly and left students to figure out such concepts for themselves.

In this paper, we attempt to identify the foundational OO programming concepts that are involved in design patterns. Prerequisite OO concepts required for understanding design patterns are not novel and some of these like inheritance and polymorphism are listed in [2] and [4]. Our list of foundational concepts is therefore an attempt to expand on such lists of prerequisite OO concepts and to unpack the other conceptual building blocks of design patterns. So by 'foundational' we do not necessarily mean 'prerequisite' as indicated by [2] and [4]. Some are prerequisite, but many foundational concepts can be presented to the students while a design pattern is being taught. In fact, design patterns often form an excellent vehicle for explaining certain important object-oriented concepts and principles.

Our reductionist approach of breaking design patterns into their foundational building blocks does not mean that we claim it is sufficient for students to understand design patterns properly merely by studying these or any other foundational concepts. Furthermore, there are different levels of understanding involved in learning design patterns, extending from having a broad but shallow overview to the in-depth understanding that is required to apply design patterns in complex programming problems. For the purposes of this paper, however, understanding design patterns simply means having sufficient knowledge to implement them in programming problems of a limited scope.

This paper is divided into four main sections (besides the introduction and the summary). Section 2 lists and describes the foundational concepts that we have identified. In Section 3, an analysis of one design pattern is given in terms of these foundational concepts, to give an idea of how the analysis was performed. In Section 4, we provide a table of many of the design patterns described in [2] with the foundational concepts involved in each. A discussion of some uses of this analysis is provided in Section 5.

2. FOUNDATIONAL CONCEPTS
We have identified a list of foundational concepts for understanding design patterns by analysing those described in [2]. The concepts identified can be categorized into two types, namely programming constructs available in OO programming

languages and programming concepts, which are generally conceptual ideas essential in OO programming. For example, a *class* as a construct refers to the syntax and structure for defining a class in a programming language but the *purpose of a class* is an abstract but essential concept irrespective of the programming language used.

The foundational concepts that we have identified are grouped according to different themes rather than on whether they are programming constructs or concepts. For example, constructs and concepts relating to classes are grouped under the theme of **Class**. Of course, the concepts identified in a theme can be based on or related to the concepts listed in other themes. For example, the foundational concept of *polymorphism* is built on the concepts listed under the themes of **Class** and **Inheritance**.

2.1 Class

- *Class* refers to the construct for defining a class.
- *Data members* (also called *member variables*) refer to the attributes of the objects of a class.
- *Member functions* (also called *operations*) refer to the functions that define the behaviour of the objects of a class.
- *Accessors* are member functions that do not change the values of the data members of the object.
- *Mutators* are member functions that change the values of data members of the object.
- *Constructors* refer to the member functions of a class that are invoked at the time of object initialisation.
- *Class variables* (also called *static data members*) refer to the data shared among the objects of a class, which can exist and be accessed without any objects of a class.
- *Class functions* (also called *static member functions*) refer to the functions of a class, which can be invoked without any objects. They generally only refer to class variables.
- *Access modifiers* refer to the modifiers with which data members, member functions, class variables and class functions of a class are qualified, determining the access restrictions of these elements within and outside the class.
- *Encapsulation* refers to the combining of data and functions so that access to the data from outside the class can only be attained by means of the functions.
- *Purpose of a class* refers to what is modelled by a class, i.e. the concept represented by the class in the application (e.g. a physical object, a process) [8].

Note that we have omitted some constructs like destructors, local variables, and function overloading, which are important for OO programming but are not directly necessary for an understanding of design patterns.

2.2 Object

- *Object* refers to an instantiation of a class.
- *State of an object* is defined by the data held by the data members of an object at a given time.
- *Object structure* refers to a linked list or tree, or array of objects existing at run time.

2.3 Inheritance

- *Inheritance* is the relationship defined between two classes, when one class (*subclass*) is derived from another (*superclass*). By derivation we mean the subclass has its own copies of all data members and shares the member functions of the superclass.
- *Multiple inheritance* is the relationship defined between classes, where one class (subclass) is derived from more than one other class (superclasses).
- *Class hierarchy* refers to a group of classes that are related to one another via an inheritance relationship.
- *Subclassing* refers to an inheritance relationship where the relationship is mainly to reuse code from the superclass and where the subclass does not necessarily satisfy an *is-a* relationship with the superclass.
- *Subtyping* refers to an inheritance relationship where the subclass satisfies an *is-a* relationship with the superclass. However, this does not exclude reuse of code by the subclass from the superclass.

2.4 Abstract, pure abstract and concrete class

- *Abstract function* refers to a member function which is only declared but not defined in a class.
- *Abstract class* refers to a class which has at least one abstract function.
- *Pure abstract class* (also called an *interface*, as in Java) refers to an abstract class which contains only abstract functions.
- *Concrete class* refers to a class which does not have any abstract functions.

2.5 Function overriding

- *Abstract function overriding* refers to the definition of a function in a subclass which is abstract in its superclass.
- *Partial overriding* refers to a function implementation in a subclass which re-defines a function defined (with the same signature) in the superclass but makes use of the functionality defined in that function.
- *Complete overriding* refers to a function implementation in a subclass which provides a new implementation for a function defined (with the same signature) in its superclass.

2.6 Class associations

- *Aggregation* refers to the relationship between two classes where an object of one class is contained in objects of the other class. The one might be a data member of the other, or have a pointer data member of the other class pointing to it.
- *Composition* refers to a variation of aggregation where the lifecycle of the contained objects is managed by the container object.
- *Association* refers to the relationship between two classes when one class refers to another class in ways other than inheritance, aggregation or composition. This could be in the form of one class using an object of the other class as a local variable, or as the parameter of a member function.

2.7 Object communication

- *Unidirectional object communication* refers to the communication between two objects where only one object can invoke functions of the other object [3].
- *Bidirectional object communication* refers to the communication between two objects where both objects can invoke functions of one another [3].
- *Polymorphism* refers to a member function call that is bound to different implementations at run time (using *dynamic binding*) depending on the type of the object it is called on [5]. This is achieved by a reference to a superclass that may refer to objects of its subclasses (called *polymorphic assignment*).
- *Delegation* refers to an object achieving a desired behaviour by calling functions of another object.
- *Inverted control* refers to a function in a superclass calling a function implemented in a subclass [2].

2.8 Managing complexity and designing for change

- *Separation of concerns** refers to the design principle where classes perform distinct tasks to provide a solution to a given problem. This can be applied to a single class by designing it to handle only one task or responsibility.
- *Programming to an interface* refers to the design principle of defining an abstract class and one or more concrete classes derived from it, so that a client doesn't need to know anything about the concrete implementations [2].
- *Reuse** is a generic term, which encompasses different ways of reusing code via inheritance, delegation, composition, aggregation and/or association.
- *Coupling** refers to the extent to which one class relies on other classes for its correct functionality or its ability to perform its responsibilities.
- *Internal cohesion** in a class refers to how well it achieves a single task [6].
- *External cohesion** refers to the extent to which a group of classes work together to achieve a purpose [5].
- *Extensibility** refers to the extent to which (or ease of which) a class or a number of classes can be reused so that their functionality is extended.
- *Flexibility** refers to the ease with which a class or a number of classes can be reused or extended in the same or different applications.

Concepts marked with an asterisk (*) are 'interpretive' in the sense that a deeper analysis is required to determine the extent to which they are present in a design pattern. The unmarked concepts are much easier to determine (yes or no), either from the UML diagram or the description of a design pattern or from the implementation.

2.9 Unified Modelling Language (UML)

Since design patterns provide solutions at an abstract level, it is useful to represent abstractions in a diagrammatic form using UML. In fact, the specification of a design pattern always includes a UML class diagram. Hence, in addition to the list of constructs and concepts listed above, it is essential for students to have an understanding of the UML representations of at least the related constructs.

3. EXAMPLE ANALYSIS: THE ADAPTER PATTERN

We now provide a detailed analysis of the Adapter pattern to demonstrate how we determined the list in Section 2, and how we selected the concepts involved in a particular design pattern. A brief intended purpose and the UML diagram of the design pattern is included as a starting point. However, no attempt has been made to discuss the intricacies, subtleties or variations beyond identifying and justifying the foundational concepts.

The Adapter pattern provides a solution for making incompatible interfaces work together. The context is common where a number of classes conform to an interface, but where one class does not, and we need to get it to conform to that interface. For example, say we have classes for different types of objects that can be resized and moved in a graphical application, and we have another type of graphical object that we want to be resized and moved in the same way, but whose class definition (i.e. names and ways of using its member functions) does not match the other classes. Then we can apply the Adapter pattern to adapt the interface of the odd class to match the others.

The purpose of the Adapter pattern can be achieved by using either a Class Adapter or an Object Adapter, as depicted in the following UML diagrams:

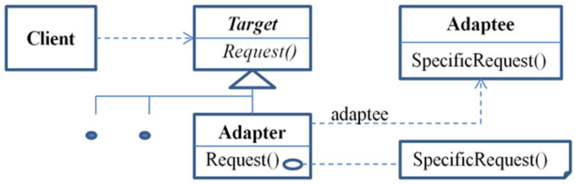

Figure 1: Object Adapter [2]

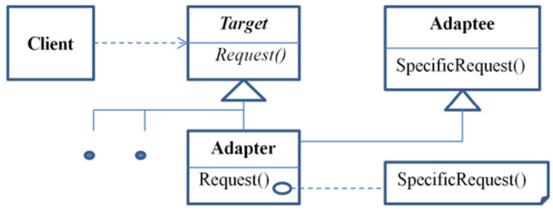

Figure 2: Class Adapter [2]

In Figures 1 and 2, both forms of the Adapter pattern require an understanding of the *class* and *member function* constructs. There is an *inheritance* relationship between `Target` and `Adapter`. `Target` is a *pure abstract class* because it consists of only *abstract functions* and its *concrete subclasses* must *override* the abstract functions. `Target`, together with all its subclasses (including `Adapter`), form a *class hierarchy*. Since all these subclasses are *programmed to an interface*, namely `Target`, the client can invoke the `Request()` function *polymorphically*.

The Object Adapter *constructs* an `Adaptee` *object* which is generally specified as a *data member* of `Adapter`. This means that `Adapter` has an *aggregation*, *composition* or *association* relationship with the `Adaptee`. The Object Adapter uses *unidirectional object communication* between `Adapter` and `Adaptee` objects.

The Class Adapter makes use of *multiple inheritance* to adapt the interface of `Adaptee` to that of `Target`. The relationship between `Adapter` and `Adaptee` in the Class Adapter can be seen as *subclassing* since the main goal is to reuse code rather than satisfying an *is-a* relationship.

In both forms of the Adapter pattern, the *purpose of the class* `Adapter` is dependent on the application context. While the Class Adapter demonstrates code *reuse* using inheritance, the Object Adapter demonstrates code reuse via *delegation*. Both forms support *extensibility* by allowing new subclasses of `Target` to be added to the existing structure, where the subclasses may or may not be additional adaptations of existing classes. The ability to be extended for additional adaptations with minimal changes to the existing classes makes it a *flexible* solution.

Depending on the aspects modeled in various subclasses (including `Adapter`) of `Target`, this design pattern *separates concerns* into various subclasses of `Target`. `Adapter` (in both forms) is *internally cohesive* by dealing with the single task of adapting `Adaptee`'s interface to that of `Target`. All classes in the Adapter pattern are *externally cohesive* by working together to contribute to the purpose of the pattern. Both forms remove *coupling* between client and `Adaptee`, and `Adaptee` can function independently of the `Adapters`.

In terms of UML, this design pattern requires an understanding of the notations for *class*, *member functions*, *inheritance*, *abstract function*, *abstract class*, *concrete class*, *function overriding*, *object*, *delegation* and *pseudocode annotation*.

4. ANALYSIS TABLE

We analysed all the design patterns in [2] as in the example in Section 3. For brevity, analyses of a selection of fifteen design patterns, five from each category (creational, structural, and behavioural) are given and summarized in Table 1.

In the **Class** theme, we have not provided rows for all its foundational concepts. The *class* and *member function* constructs have been removed because they are present in all the design patterns. Similarly, rows for *encapsulation* and *purpose of a class* are also omitted. The former is fundamental in designing any class and the latter is either implicit in the design pattern or dependent on the application context.

In the **Inheritance** theme, we have not included a row for *class hierarchy*. If there is *inheritance* present in a design pattern, then inevitably a *class hierarchy* will be present. The concept of *subclassing* can be easily determined in design patterns but to determine whether the inheritance represents *subtyping* depends on the implementation in the application context. Since we cannot provide an entry in the table cell without considering the implementation, we have removed the row for *subtyping*.

In the theme of **Abstract, pure abstract and concrete classes**, we have merged *abstract* and *pure abstract* into one row because the distinction is relevant mainly in the application context. Similarly, the table doesn't make a distinction between the various forms of *function overriding* and different forms of associations such as a*ggregation, composition and association* because again the distinction lies in the application context.

Table 5: Analysis of design patterns in terms of foundational concepts

	Abstract Factory	Builder	Factory Method	Prototype	Singleton	Composite	Adapter	Facade	Flyweight	Proxy	Observer	Memento	Strategy	Template Method	Visitor
data members		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		
accessors		✓							✓		✓	✓			
mutators												✓			
constructors	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
class variables					✓										
class functions					✓										
access modifiers					✓										
object	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
state of an object				✓					✓		✓	✓			
object structure		✓				✓			✓	✓	✓				✓
inheritance/class hierarchy	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓
multiple inheritance							✓								
subclassing		✓	✓			✓	✓		✓	✓	✓			✓	
abstract function	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓
pure/abstract class	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	
concrete class	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓
function overriding	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓
aggregation/ composition/ association	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓
unidirectional communication	✓	✓		✓		✓	✓	✓	✓	✓		✓	✓		
bidirectional communication											✓				✓
polymorphism	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓
delegation	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓
inverted control			✓											✓	
programming to an interface	✓	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓

The table only includes one row for *programming to an interface* from the theme of **Managing complexity and designing for change**. All design patterns aim to *separate concerns* into different classes or groups of classes and some of these concerns are application dependant. The concepts of reuse, coupling, internal and external cohesion, extensibility and flexibility are also excluded in the table because these concepts require detailed explanations, which cannot be justified by a simple 'yes' or 'no' entry in the respective cell. For example, in the Adapter pattern, one can find examples of decoupling (between `Client` and `Adaptee`), abstract coupling (between `Target` and `Client`) and coupling (between `Adapter` and `Adaptee`). Also `Adaptee` can function (and exist) independently of `Adapter` , but not the other way around.

UML notation is also not included in the table because it is necessary in all design patterns.

An entry in a cell (✓) means that the specific concept is part of the design pattern (as discussed in [2]). The absence of an entry in a cell does not necessarily mean that the concept is completely irrelevant in the design pattern. For example, the concept of *object* is so fundamental that one is unlikely to use a design pattern without ever creating objects. However, only design patterns that explicitly require creating objects (for example, creational patterns) have *object* as a foundational concept in the table. It should be noted that, as intended by the idea of design patterns, the application context in which a design pattern is applied determines the finer implementation details. Hence a design pattern without an entry in a cell is not prohibited from using that concept when applied in an application context.

Not including a concept or merging concepts in the table does not mean that such concepts are not important in understanding design patterns. We believe that an understanding of all foundational concepts is important because such knowledge is essential when applying design patterns in various application contexts. Needless to say, a firm grasp of all the foundational constructs and concepts of OO programming will place one in a better position to tailor design patterns for various application contexts, or even to create new design patterns for other problem contexts.

5. USES OF THIS ANALYSIS

Analysing design patterns in terms of their building blocks has been a valuable exercise for a number of reasons:

Firstly, it has helped us to identify the prerequisite knowledge we expect students to understand before they have to deal with the intricacies of design patterns. We plan to adjust the syllabi of our prerequisite modules to cover the necessary concepts more thoroughly.

Secondly, when teaching a particular design pattern, we plan to use the table of foundational concepts as a checklist to make sure we have taught all the relevant foundational concepts.

Thirdly, the process of determining the foundational concepts involved in the selected design patterns has given us (as lecturers) a better understanding of these patterns. So much so that we plan to give our students exercises based on this process. There are various possibilities:

(i) Get students to try to break a design pattern down into foundational concepts.
(ii) Give students the list of foundational concepts and get them to identify and explain which are involved in a particular design pattern.
(iii) Give students one column of the table, i.e. a design pattern and the foundational concepts we identified in it, and get them to show or explain how each concept occurs in the pattern.

6. SUMMARY

In this paper, we have argued that the commonly accepted list of prerequisite OO concepts can be expanded to a broad list of foundational concepts that are necessary for understanding design patterns. Some are programming constructs, and others are more abstract concepts and principles. Some are clearly present or not in particular patterns, and others are more interpretive in nature, i.e. they are present to some degree or in some way in a pattern. The presence of others is dependent on the application or adaptation of a particular design pattern to a particular context or problem. We have analysed fifteen design patterns in terms of their foundational concepts and provided some of the results of the analysis in table form for easy reference.

We have explained why we think this exercise is useful, and how we plan to use it in adjusting the curricula of our programming modules, to improve our teaching, and for testing whether students understand the building blocks of design patterns and how they contribute to the purpose of a design pattern.

We hope that this study will be useful to other lecturers teaching design patterns.

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Factors Influencing E-learning Motivation and Its Impact on LMS Usage

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ABSTRACT

This paper investigates the factors that influence the use of learning management systems by university students. Undergraduate and Postgraduate Information Systems students from the University of the Witwatersrand participated in this study. The study centred on the factors that influence e-learning motivation and its impact on the use of learning management systems.

The results of this study revealed that assurance and responsiveness have a positive influence on an individual's e-learning motivation. In the presence of assurance and social influence, the effect of responsiveness on e-learning motivation was not significant.

Content quality was also found to have no effect on e-learning motivation in the presence of assurance, although a relationship between content quality and e-learning motivation was found in the absence of assurance.

Social influence positively influenced e-learning motivation which in turn positively influenced behavioural intentions to use a learning management system.

The relationships between social influence, behavioural intentions and e-learning motivation, was moderated by age. This was also translated in terms of academic level of study. An individual's behavioural intentions positively influence use of LMS. Studies need to be contacted considering the relationship with satisfaction.

Lecturers need to understand factors that influence e-learning motivation as this can help in ensuring that students are motivated enough to use LMS due to reduced student anxiety thus deriving planned benefits. Lecturers' ability to exhibit assurance is vital as it greatly influences a student's e-learning motivation. This would not only encourage students to use a learning management system but also create an atmosphere that fosters collaboration amongst the students.

Caution should be taken when generalising these results because the research sample largely constituted of undergraduate IS students, the results do not necessarily reflect the entire South African students' population.

E-Learning in High Schools: An Uncomfortable Zone for Teachers

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ABSTRACT

E-learning can be seen as a means to increase the global competitiveness of a nation. Despite this developmental role, previous research indicates that the use of Information and Communication Technology for teaching and learning purposes has not been met with a great deal of success in South African schools. Consequently, this study investigated the factors which affect the usage of ICT by secondary school teachers around Johannesburg. Following international literature, the study utilized quantitative methods to explore the relationship between ICT usage and the level of ICT infrastructure, level of IT support, the teachers' attitude towards ICT, teachers' attitude towards eLearning, teachers' perceived ease of use of ICT, teachers' perceived usefulness of ICT, and technology anxiety. Teachers' age and gender were also taken into consideration. The results of this study showed that only the attitude of teachers towards the use of ICT for teaching and learning purposes, and the perceived ease of use of ICT predict teachers' use of ICT for teaching. The findings suggest that if teachers believe that the use of ICT has the potential to enhance and improve teaching and learning, they are more likely to integrate ICT into their teaching. In addition to this, teachers who believe that interacting with computers does not require a lot of mental effort, are also more likely to make use of ICT in the classroom. This implies that ICT usage can be improved if teachers' training programmes were to incorporate some form of e-learning. This could help some teachers to develop a positive attitude towards e-learning which can be translated into the actual usage in classrooms. As such the department of education must request for ICT usage plans from school as well as incentivise teachers who use ICT.

The Internet of Things Technologies in Teaching, Learning and Basic Education Management

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ABSTRACT

The South African basic education system faces a number of challenges including ensuring access to education for all, access to an adequate infrastructure such as to laboratories, improving the quality of education across the value chain, a reduction in the supply of qualified teachers due to the impact of HIV/AIDS and high learner dropout, to name but a few. This paper proposes the adoption of internet of things technologies in improving learning, teaching and basic education management. The internet of things is what happens when everyday ordinary objects have inter-connected microchips inside them. These microchips help not only keep track of other objects, but many of these devices sense their surrounding and report it to other machines as well as to the humans for decision-making. The paper identifies areas of health in education, teacher education, learner support, social mobilisation and support services, planning and delivery oversight, quality assessment, inclusive education and curriculum policy, support and monitoring as areas where internet of things technologies can be adopted. A number of internet of things technologies that can be of value in these areas are identified as examples, both from local and international perspectives. Radio frequency identification for the tracking and tracing of food supply in the school nutrition programme, the prototype solar-powered classroom that incorporates WiFi cameras designed to interact with 3G, remote-controlled laboratories and automated tracking of transport that takes learners to school are some such examples of the applications of the internet of things that can support and enhance education.

Educating in the Changing Environment of Computer Applications Technology

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ABSTRACT

The merit of the study reported on, and relevance to this conference, is justified in terms of frequent changes associated with technology that educators have to contend with. We specifically investigated research questions relating to how educators of Computer Applications Technology adapt to such changes. The paper draws on mostly recent research findings on the topic, in a literature review covering aspects related to instructional technology and computer-based instruction, information technology in educator education, newly qualified and experienced educators, methodological weakness in previous studies and research in the Southern African context. The study is located within a conceptual framework that clarifies definitions and descriptions around technology relating to the use of tools, Information and Communication Technology, Computer Applications Technology, computer literacy courses, instructional technology as a tool for teaching and learning and e-learning. The mixed method research approach that was used consisted of mainly qualitative data, obtained via semi-structured interviews and supplemented by the quantitative biographical details of respondents. The research design is described, including the consideration of issues related to the methods of data collection employed as well as the population and sampling, reliability and validity. Discussion and analysis of respondents' details and a summary of their responses during the semi-structured interviews are presented. These include aspects related to e.g. participants' opinions about the role that experience plays when adapting to technology changes, and are in some instances connected back to literature. In conclusion, the findings indicate that in terms of the primary research question set for this study, most Computer Applications Technology educators in this sample readily adapt to technology changes, although it does require some effort to do so. The strength and limitations of the study are discussed, before final recommendations related to possible future research are made.

Meeting Industry Expectations for Entry Level Information Technology Employees – A Pilot Study

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ABSTRACT

Considering the relatively large number of unemployed graduates in South Africa [16], it is necessary to assess whether graduates from Higher Education Institutions (HEIs) are adequately meeting the expectations of potential employers. In addition, it is also necessary to gauge the perceptions of students about how prepared they are for employment after graduation.

The purpose of the study is to test the survey instruments which were designed to conduct a wide scale survey to compare the requirements of potential employers and the perceptions of undergraduates Information Technology (IT) students who are about to enter the job market.

The outcome of the test samples will inform the changes required to refine the questionnaires to support a large scale study to effectively establish an empirical benchmark against which periodic future reviews of IT qualifications can be conducted by different HEIs.