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STEFAN GRUNER
The South African Computer Journal has for a long time served the Computer Science and Information Systems research community in South Africa, and in particular SAICSIT. Since its inception in 1989, a total of 344 research papers were published. In a paper submitted to SACJ, and currently under review, the authors points out that virtually all of these papers address issues in the theoretical foundations of the community’s work.

To a large extent, the community of researchers supporting SAICSIT are also lecturers at tertiary educational institutions. In this capacity, they conduct reflective research on the teaching of the subject at all levels. A completely separate forum, the South African Computer Lecturers Association (SACLA), was established where these issues are addressed. SACJ has traditionally not been regarded as a forum for SACLA participants to publish any of its reflective research on the teaching.

In his final report to the SAICSIT AGM, the outgoing Editor of SACJ mentioned that he would like to see more of these reflective papers in SACJ. This was an extremely fortuitous call. The incoming Editor of SACJ was in fact involved in the organising of SACLA 2008. A number of papers from SACLA 2008 had been peer refereed and were found acceptable for publication in a journal. Hence, the decision was made to publish these papers in a special edition of SACJ.

Two issues arise from these facts:

- The issue of a forum for the publication of papers with an educational slant;
- The issue of Special Editions of SACJ.

The first is easily solved. Papers in this category can be submitted to SACJ, and will enter the normal review process. Reviewers specialising in the educational aspect of Computing will be selected, and the papers will be published in an educational section of SACJ. If enough interest is shown, a Sub-editor in this specialisation area could be appointed. So, we are hereby issuing a call for papers that concentrate on the tuition aspects of Computing.

I have received numerous requests from conference organisers to publish a selection of papers from their proceedings in special editions of SACJ. Obviously, there are many problems associated with such special editions: One question often raised by university administrators is “Why publish in a conference proceedings if you could submit the paper to a journal?” The so-called double-dipping becomes an issue when researchers claims subsidy for a conference paper as well as a journal paper. There are issues of intellectual property right and copyright, and a host of other issue. Hence it is not a simple matter to produce a special issue of SACJ. We will in due time publish a procedure through which organisers can apply to have their papers published in SACJ.
Knowledge, skills and strategies for successful object-oriented programming: a proposed learning repertoire

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ABSTRACT

Third year Computer Science students were studied in order to determine which knowledge, skills and strategies they used during an object-oriented programming task. Quantitative and qualitative methods were used to analyse their computer programs and associated thinking processes. Successful programmers applied significantly more cognitive, metacognitive and problem-solving knowledge, skills and strategies, also using a greater variety, than the unsuccessful ones. Based on the approaches of the successful programmers, we propose a learning repertoire of integrated knowledge, skills and strategies, which can serve as a framework to support novices learning object-oriented programming (OOP).

CATEGORIES AND SUBJECT DESCRIPTORS

D.3.3 [Programming Languages]: Language Constructs and Features – abstract data types, classes and objects.

GENERAL TERMS

Languages, Design, Performance, Reliability.

KEYWORDS

Object-oriented programming, successful, unsuccessful programmers, thinking processes.

1. INTRODUCTION

Learning and conducting object-oriented programming (OOP) is multidimensional and complex [15]. OOP requires the use of specific knowledge, skills and strategies to solve problems and write the associated programs. Successful and unsuccessful programmers differ in the way they approach and solve programming problems. An unsuccessful programmer is a person who did not achieve the stated outcomes, while a successful programmer is one who did achieve them and who dealt efficiently with problems [15]. Successful programmers possess a well-organised, carefully-learned knowledge structure [1]; they use self-regulatory processes and monitor their problem-solving activities [14] and they can solve a problem quickly, although they often appear to spend more time in problem representation [25].

These are some examples of cognitive, metacognitive and problem-solving activities that are required in programming. However, these are not merely personal or isolated learning techniques, but rather distinct activities that should explicitly be integrated to address a programming problem and solve it successfully. This paper considers the following research questions: What are the differences between the ways that successful and unsuccessful programmers apply their knowledge, skills and strategies in an object-oriented programming task? How can novices be supported in learning OOP?

The objective of the first question was an attempt to identify cognitive, metacognitive and problem-solving knowledge, skills and strategies used by successful and unsuccessful programmers in OOP. To answer the second, we attempted to integrate the approaches of successful programmers into a learning repertoire that can serve as a framework for novices learning OOP.

2. LITERATURE SURVEY

Computer programming involves a rich environment in which specific programming words, statements and constructs come together to be integrated in a tightly defined way to solve a problem efficiently. This requires high-level knowledge, skills and strategies. In general, the knowledge relates to information and skills acquired through experience or education. A skill refers to the ability to do a particular task, while a strategy is a designed plan to achieve a purpose and to solve a problem [6]. It is often assumed that students implicitly and independently master the required high-level knowledge, skills and strategies, and that teaching should focus on programming content and coding structures only. However, to be successful in the complex domain of OOP, explicit learning

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of both facets is required. This survey briefly overviews some aspects and techniques that can support successful programming.

2.1 Cognition

The concept of cognition refers to the mental processes used in the acquisition, storage, transformation and application of knowledge [25]. In this regard Bloom’s taxonomy [3] defines six types of learning, hierarchically ordered according to the level within the cognitive domain: knowledge; comprehension; application; analysis; synthesis; and evaluation. The way in which these concepts are used (or not used) can define the differences between successful and unsuccessful programmers [28], where the six associated skills are, respectively: knowledge of the programming language; interpretation of the programming problem; application of prior knowledge in a new program; analysis of the problem; design of a new program; and evaluation of the solution. Since programming is ‘extremely cumulative’, novices must progress through each of Bloom’s six levels to become truly successful [4] [28].

Recall of information can be improved by cognitive strategies [22] such as rehearsal, elaboration and organisation [2]. Rehearsal strategies, for example: focussing attention, structured recall, and distributed practice over a period of time; can support recollection and help to pinpoint important information within a context. In the programming context, programmers who repetitively sequence activities in a particular way ‘preserve the effect’, using less working capacity [17]. Elaboration helps students to integrate new information with prior knowledge by, for example: generative note taking, asking questions, summarising, and creating analogies. The organisation strategy includes extraction of the main idea from text as well as integration of concepts [2] with the goal of achieving a holistic problem solution.

2.2 Metacognition

Metacognitive knowledge is explicit knowledge of one’s own cognitive strengths and weaknesses, beliefs and conditions that affect memory performance [16][21]. Self-knowledge, task-knowledge and strategy knowledge are required in the metacognitive domain [11]. Metacognitive strategies include planning, monitoring and regulation. In programming, planning entails analysis of the problem and the identification of possible classes and methods to solve it, while monitoring guides the process of finding a solution by means of self-testing [2]. Regulation involves the continuous modification of one’s cognitive activities to determine whether the problem is being solved successfully. Bergin et al. [2] discuss self-regulated learning with regard to the performance of students in their third level of introductory OOP. They found that students with high levels of intrinsic motivation perform better and use more metacognitive-management strategies than lower performing students.

2.3 Problem solving

Different kinds of problems are solved in different ways and require different approaches. Students should understand how problems vary according to their structuredness, complexity, dynamicity and domain-specificity [20]. In this regard, programming experience and exposure play roles and Sternberg [25] suggests that experts develop sophisticated internal representations of certain kinds of problems, based on their structural similarities. Standard problem-solving strategies are: bottom-up, top-down, integrated, as-needed and trial-and-error [7] [9] [29]. Research shows that expert object-oriented programmers tend to use top-down strategies during the early phases of programming to understand systems holistically. In contrast, the same experts may use a bottom-up strategy when programming in an unfamiliar context or during program maintenance where individual parts are combined to form larger components [7].

2.4 Object-oriented programming

OOP is based on the object-oriented approach, where objects are models of real-world entities that have the responsibility of carrying out specific tasks to solve the problem [12]. OOP involves various knowledge and skills relating to data types, control structures, instantiation of objects, methods, GUI tools, exception handling, database connectivity [19], input/output validation, performance correctness [24], debugging and the development of test data. Due to the complexity of OOP, students have difficulty in applying the required activities successfully [15]. Explicit teaching and learning of high-level knowledge, skills and strategies may therefore be a requirement to support success in OOP.

3. RESEARCH DESIGN

The underlying research ethos of this study is constructivist problem solving, which refers to the students’ active construction of computer programs and application of programming constructs such as classes and objects. It also relates to the researcher’s construction of a body of knowledge regarding the students’ programming constructs, as she interprets and reflects on those programming experiences. This implies a continuous process of interpretation and reflection.

In a mixed methodology, both quantitative and qualitative research methods were used to analyse participants’ computer programs and the associated written thinking processes. Quantitative methods include statistical calculations such as descriptive statistics, practical significance and correlation. As a qualitative research practice, grounded theory was applied to guide the systematic collection of data and to generate a model inductively from the ongoing data collection and analysis to explain the specific phenomenon [8][13].

3.1 Data collection

The research was conducted over a period of two years. The participants (n = 48) came from two groups: the first group, namely 2005, consisted of 11 BEd and 17 BSc 3rd year students, and the second group, namely 2006, comprised three BEd and 17 BSc 3rd year students. Students from both groups took Computer Science as a major subject. Each participant had to create an object-oriented program relating to leap years. It was an open-ended question and participants had to decide personally which calculations were necessary in the program. However, some requirements were included to direct the programming process. At the very least, the students should write a Date class program to calculate which years are leap years and the difference between any two dates in the range 1 January 1800 to a later date. A Test class program was also required to determine whether the output of the Date class was correct. The programs could be done in either Delphi or Java. During the major process of programming the Date class task, participants were required to record their thinking and problem-solving processes in writing.

Data collection included both the computer programs and the recorded thinking processes. triangulation was applied by investigating data from these two sources, i.e. the coded programs and the associated thinking processes written by participants as they considered the problem and coded their
solutions. Finally, coherence between the different data sources was investigated to identify patterns of meaning and to describe the emerging theory that leads to the learning repertoire.

3.2 Data analysis

Two approaches were followed. In the first approach, each program itself and the recorded thinking processes were evaluated, using as an instrument, a set of measurement criteria that had emerged from the literature review. The 24 criteria (or subcategories) shown in Table 1 originate from four major categories: cognitive knowledge and skills; metacognitive strategies; problem-solving strategies; and OOP knowledge and skills. Measurement of 23 of the criteria was scored on a 4-point scale where 1 indicates poor performance and 4 an excellent performance. For the problem-solving category with its single criterion, participants could use more than one strategy, so a maximum of 8 was allocated instead of 4. Participants who used the trial-and-error strategy received zero, since it was not considered an acceptable problem-solving strategy. The 24 criteria thus score a total of 100. As the indicator of ‘successful’ programming, participants had to obtain 3 or 4 for the ‘Correctness of output’ subcategory (last criterion in Table 1), relating to evidence of correct program output and the test data used. Based on this approach, there were 11 successful and 37 unsuccessful programmers.

The scores were analysed by descriptive statistics to determine the means and standard deviations of successful and unsuccessful participants for all criteria and for the overall categories. Practical significant differences (effect size) between successful and unsuccessful participants were determined for all criteria, as shown in Table 2. Guidelines for the interpretation of effect size are as follows: $d = 0.2$ small effect; $d = 0.5$ medium effect; $d = 0.8$ large effect [5]. Values $> 0.8$ mean that the effect size of constructs is regarded as practically significant [10]. However, Thompson [27] warns that researchers should avoid using these guidelines in an overly rigid way. In order to determine correlations between the cognitive, metacognitive, and OOP constructs, the Spearman ranked correlation coefficient was used, as shown in Table 3. The correlation is interpreted as follows: $r = 0.1$ small effect; $r = 0.3$ medium effect; and $r = 0.5$ large effect [5]. Data with an $r$-value $\geq 0.5$ is considered as practically significant [10].

The second analysis approach investigated the thinking processes of participants, using the qualitative analytical software package, Atlas.ti. The purpose was to identify various themes that emerged from the recorded thinking processes. The researcher allocated codes to particular segments in the typed textual data until sufficient similar patterns were identified, indicating that saturation had occurred. After the codes were grouped and categorised, various themes were identified.

![Table 1. Measurement criteria and associated categories](chart)

<table>
<thead>
<tr>
<th>Category</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive knowledge and skills</td>
<td>Knowledge (4) Evidence of knowledge of the programming language</td>
</tr>
<tr>
<td></td>
<td>Comprehension (4) Interpretation of the problem</td>
</tr>
<tr>
<td></td>
<td>Application (4) Application of prior knowledge in a new program</td>
</tr>
<tr>
<td></td>
<td>Analysis (4) Analysis of the problem – breaking it down into steps</td>
</tr>
<tr>
<td></td>
<td>Synthesis (4) Designing a new program</td>
</tr>
<tr>
<td></td>
<td>Evaluation (4) Evaluation of the solution</td>
</tr>
<tr>
<td>Metacognitive strategies</td>
<td>Planning (4) Evidence of planning during programming</td>
</tr>
</tbody>
</table>

| Problem-solving strategies (8) | Application of problem-solving strategies: bottom-up, top-down, integrated, as-needed |
| OOP knowledge and skills       | Program requirements analysis (4) Analysis of the program requirements |
|                                 | Programming techniques (4) *Programming techniques used: indentation, readability, variable names and declaration |
|                                 | Programming statements (4) *Application of the correct use of programming statements |
|                                 | User-friendliness (4) Application of user-friendliness and usability |
|                                 | Classes and objects (4) Designing of classes and instantiation of objects |
|                                 | Method application (4) Application of methods such as constructors, mutators and accessors |
|                                 | Access control (4) *Decision on the accessibility: public, private |
|                                 | Parameter passing (4) *Application of parameter passing: number, order, type of variables |
|                                 | Reasoning (4) Application of reasoning skills in OOP |
|                                 | Exception handling (4) *Application of exception handling |
|                                 | Program structure, scope (4) *Application of program structure and scope |
|                                 | Successful programming (4) Actual solution to the problem |
|                                 | Program evaluation (4) Evaluation of the Date class and Test class |
|                                 | Correctness of output (4) Evidence of correct program output and test data used |

TOTAL (%)

*Criteria selected specifically to reflect on general characteristics of programming (Sebesta, 2004:8).

### 3.3 Quantitative findings re participants’ programs and thinking processes

Table 2 summarises the measurement criteria for each category and its subcategories, giving the: mean values, standard deviations and effect size for successful and unsuccessful participants, respectively. The means for cognition, metacognition and OOP are higher for successful participants than for the unsuccessful. Practical significant differences with a large effect size were found between successful and unsuccessful participants within all subcategories except for knowledge, comprehension, classes and objects, access control and parameter passing, where practical significant differences of a medium effect size occurred.

<table>
<thead>
<tr>
<th>Category</th>
<th>Unsuccessful participants (37)</th>
<th>Successful participants (11)</th>
<th>Practical significance (effect size)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{x}$ s</td>
<td>$\bar{x}$ s</td>
<td>d</td>
</tr>
<tr>
<td>Cognition</td>
<td>3.05 0.71</td>
<td>3.85 0.20</td>
<td>1.13*</td>
</tr>
<tr>
<td>Knowledge</td>
<td>3.65 0.68</td>
<td>4.00 0.00</td>
<td>0.51</td>
</tr>
<tr>
<td>Comprehension</td>
<td>3.54 0.65</td>
<td>4.00 0.00</td>
<td>0.71</td>
</tr>
<tr>
<td>Application</td>
<td>3.32 0.78</td>
<td>4.00 0.00</td>
<td>0.87*</td>
</tr>
</tbody>
</table>

* Criteria selected specifically to reflect on general characteristics of programming (Sebesta, 2004:8)
In all the constructs measured, there were correlations in cognition, metacognition and OOP knowledge and skills. Table 3 shows Spearman correlations between pairs of variables. In the analysis of the participants’ thinking processes in association with their programming of the Date class, namely: cognitive knowledge, skills and strategies; metacognitive knowledge, skills and strategies; problem-solving knowledge, skills and strategies; errors and problems in programming; and additional support in programming.

### Table 3. Correlations between cognition, metacognition and OOP constructs

<table>
<thead>
<tr>
<th>Construct</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognition</td>
<td>0.63**</td>
</tr>
<tr>
<td>Metacognition</td>
<td>0.89**</td>
</tr>
<tr>
<td>OOP construct</td>
<td>0.73**</td>
</tr>
</tbody>
</table>

** Practically significant (Steyn, 2002).

### 3.4 Analysis of the thinking processes with Atlas.ti

Five main themes emerged in an inductive grounded-theory approach from the analysis of the participants’ thinking processes in association with their programming of the Date class, namely: cognitive knowledge, skills and strategies; metacognitive knowledge, skills and strategies; problem-solving knowledge, skills and strategies; errors and problems in programming; and additional support in programming.

#### 3.4.1 Theme 1: Cognitive knowledge, skills and strategies

The unsuccessful participants did not refer to explicit evaluation skills as in Bloom’s taxonomy nor to cognitive strategies. Responses indicating that they used some of the skills in Bloom’s taxonomy are: I find out when it is a leap year; I first determine the requirements; Which variables do I need? Firstly, I thought about the class structure; Which methods should be in the class? I need a method to convert the number of days. *P31* refers to Participant 31, etc.

Successful participants applied the full set of skills from Bloom’s taxonomy, some examples being: A programmer should understand basic principles; I received the date as a string and separated it into days, months and years. During synthesis and evaluation, participants integrated various methods in the class: I also need a method to test for valid dates. Participant 40 referred to evaluation skills when he indicated that his program was working 100%. Participant 23 elaborated the strategy in the following statement: When designing the class, I ask myself about the general and special cases in each situation.

#### 3.4.2 Theme 2: Metacognitive knowledge, skills and strategies

Unsuccessful participants reflected and acknowledged their programming weaknesses. Two examples are: I have the correct idea but cannot apply it; I do not have a plan … Some useful responses of unsuccessful participants about metacognitive strategies are: I re-read the question with attention; I could send the date to the constructor; I forgot to insert close brackets; I have determined the difference in days but was incorrect with one day.

Successful participants applied a spectrum of metacognitive activities: I read the question carefully and determined what was being asked? What are the specifications? Participant 32 used planning, monitoring and regulation strategies: Many questions were asked to determine the purpose, parameters, input, output, and problems of the programming task (planning). He also reflected on the programming task: Problems? Many! The method was difficult … and I should include many exceptions for leap years. The biggest problem was the difference between days. I have a few

There are possible correlations between participants’ expertise in cognition, metacognition and OOP knowledge and skills. Table 3 shows Spearman correlations between pairs of these variables. In all the constructs measured, correlations were greater than 0.5 and therefore relevant in practice. The high correlation between cognition and the OOP construct (r = 0.89) implies that certain predictions can be made regarding successful programming in cases where participants make effective use of all the cognitive activities. The correlation between metacognition and OOP (r = 0.73) suggests that the use of metacognition and reflection can support problem-solving performance in OOP.
ArrayOutOfBoundsException exceptions. This was solved with diagrams (monitoring and regulation).

3.4.3 Theme 3: Problem-solving knowledge, skills and strategies

Unsuccessful participants found it difficult to follow specific steps during problem solving: I do not know if it is correct. I have typed all the things that I thought should be in the program [P31]. I … will try to code by means of trial-and-error [P34]. Participant 6 used the bottom-up strategy to solve the problem: I will complete the code for a specific component before continuing with the next component. Successful participants described their systematic problem-solving steps in more detail. For example: I determine the input, design the interface and basic components, process and then test the input [P44]. Participant 32 used the top-down strategy when he indicated: I will start with the framework for the Date and Test class, headings, import given methods, etc.

3.4.4 Theme 4: Errors and problems in programming

This theme highlights examples of errors and problems, some of which also relate to a lack of metacognitive strategies. Unsuccessful participants pointed out: I wonder why I typed some of this code, because I will not use it [P39]; …exception handling is complicated [P33]. Some participants could not apply exception handling or interpret errors [P31, P33]; others used incorrect syntax [P39] and could not compile the program.

Successful participants were able to diagnose and correct their errors. Two examples from P32: I had problems determining a specific date format [P32]; …the Difference() method was difficult and I should provide for many exceptions…[P32].

3.4.5 Theme 5: Additional support in programming

Both unsuccessful and successful participants referred to supplementary means of support during the programming process: I used…previous code [P48]; textbooks [P30]; …previous…assignments [P44]; and Wikipedia.com for the requirements of leap years [P29].

4. RESEARCH QUESTIONS REVISITED

This section answers the first research question: What are the differences between the ways that successful and unsuccessful programmers apply their knowledge, skills and strategies in an object-oriented programming task? The answer relates to the three major themes that emerged from the grounded theory analysis: cognitive-, metacognitive- and problem-solving knowledge, skills and strategies that unsuccessful and successful participants apply/do not apply in the process of a programming task.

4.1 Emerged themes

We discuss three major themes that emerged from the grounded theory approach.

4.1.1 Cognitive knowledge, skills and strategies

Unsuccessful participants battled to decompose the problem scenario and to relate subparts to the overall structure. With regard to actual programming, they could not readily apply higher-order thinking skills. Although they used knowledge and comprehension skills, their programs indicate that they debugged and evaluated the code without using detailed application and analysis skills. As a consequence, they had problems in interpreting their errors, they could not complete the program, and many did not obtain output.

For the higher-order thinking skills (analysis, synthesis and evaluation) required for programming, the successful participants received a mean value of more than 3.5 on a 4-point scale. Their ability to apply all the levels of Bloom’s taxonomy in a task was clear and they achieved a high level of accuracy in solving the problem. It is notable that they spent more time on the analysis phase and differentiated how parts are inter-related in the complete program. Their performances illustrate that programmers should understand the problem precisely, interpret and evaluate their programming solutions.

Only one successful participant explicitly mentioned a cognitive strategy that was used during programming. Possible reasons could be that participants did not verbalise knowledge about these strategies, they did not use cognitive strategies, or they did not know how to apply such strategies in programming. In this regard, Bergin et al. [2] show that cognitive strategies are not as useful in the learning of introductory OOP as they are in other domains.

4.1.2 Metacognitive knowledge, skills and strategies

Unsuccessful participants found it difficult to apply metacognitive activities during programming; they encountered problems in monitoring and regulating their cognitive resources. Very few of them applied any form of regulatory strategy. They could not easily reflect on the task and their own understanding of it, and found it difficult to manage their thinking and reasoning.

By using detailed planning strategies, successful participants were able to complete their tasks and produced high quality solutions. Most participants monitored their progress and effectively managed their cognitive resources in the process of finding a solution (Table 2). The regulation strategy of successful participants was slightly lower than 3 (X = 2.82), which implies that they could improve further on regulatory strategies during programming. These findings correspond with Hertzog and Robinson [18], who suggest that monitoring plays a vital role in cognitive performance of complex problem solving and guides the process of finding a solution.

4.1.3 Problem-solving knowledge, skills and strategies

Unsuccessful participants did not obtain the required program output. Some encountered problems in systematically applying problem-solving strategies. Instead, they spent time iterating through their programming code to address errors, without understanding which sections were incorrect and how to rectify them. Such participants were much less accurate in their efforts to reach an appropriate solution. Although most of the unsuccessful participants used a bottom-up strategy (27), some wrote that they worked without using any specific problem-solving strategies (2). Two used trial-and-error, three used a top-down strategy, and three used the integrated strategy.

Successful participants had considerable domain knowledge and highly efficient problem-solving skills, which they were able to apply successfully in the task. Seven of them used the bottom-up strategy, two the top-down, and two the integrated strategy during program comprehension. None of the successful participants used the trial-and-error strategy. This appears to indicate that it is not a successful approach in OOP, whereas all the other problem-solving strategies were used effectively. The second research question is: How can novices
be supported in learning OOP? It is answered by presenting a proposed learning repertoire.

4.2 Proposed learning repertoire

The constructivist problem-solving approach supports active involvement of students in constructing computer programs and applying constructs such as classes and objects. This paradigm also acknowledges the researcher’s part in the construction of knowledge about the programming constructs of students, where action, interpretation and reflection are vital.

Educators need to play supportive roles that facilitate the acquisition of appropriate activities as students learn to apply the sum of their knowledge, skills and strategies in programming. OOP is a dynamic and constructive process involving various actions and dimensions. Since its complexity can be overwhelming, we propose a learning repertoire in Figure 1 to serve as an integrated framework to support novices in learning OOP. The content of the repertoire is drawn from the empirical research, which highlights ways in which successful participants solved the programming problem. Subsets of the repertoire can be selected and used for a particular context or task.

Various dimensions are integrated in the repertoire, which explicitly distinguishes between knowledge and skills on the one hand, and strategies on the other. Knowledge and skills form the core. Cognitive knowledge and skills on all levels of Bloom’s taxonomy are required for the understanding, designing, coding and testing of a programming problem. Specific emphasis is placed on the higher-order thinking skills such as analysis, synthesis and evaluation. Setting of goals, a high level of motivation, and knowledge about specific tasks are required in the metacognitive domain. In addition, adequate programming knowledge and skills are essential to the ability to complete a new program successfully.

Dynamic interaction, indicated by the arrows in Figure 1, occurs between the core sections of cognitive, metacognitive and problem-solving activities. As an example, successful object-oriented programming requires the ‘application’ of skills from Bloom’s taxonomy, particularly synthesis and evaluation to determine whether a program is correct and to rectify it if not. The dimensions in Figure 1 are supported by strategies lying outside the core. Students can use these strategies to enhance the acquisition of knowledge and skills, and can apply them during the processes of Construction, Reflection, Selection and Application in OOP. The three dashed arrows on the left, the right and below the core indicate the dynamic and continuous use of cognitive, metacognitive and problem-solving strategies in the first three processes, while the bold arrow above the core relates to the application of these activities in designing new programs and maintaining existing ones.

• Construction

The use of cognitive strategies can enhance acquisition of the knowledge and skills in Bloom’s taxonomy. Rehearsal supports the learning of facts about OOP (knowledge) and the grasping of programming content (comprehension). Elaboration can facilitate the use of previously-learned material in new situations (application) and the decomposition of a problem into subproblems (analysis). The organisation-and-integration strategy can support programmers in combining objects, methods and attributes in a class (synthesis) to program and test the correct solution (evaluation). Object-oriented programmers should be actively involved in their tasks, using prior knowledge and applying a repertoire of knowledge and skills to help them recall information and organise it in memory during the process of constructing a program.

• Reflection

Students should reflect on their cognitive processes during OOP by conducting deliberate planning, monitoring and regulation. They should question themselves, discover misconceptions, identify errors and continuously modify their programs in order to succeed. Such reflection places them in control of the programming task as they explicitly query the correctness of their code and reflect on their prior thinking to identify errors and correct flaws. Appropriate responses to feedback and the continuous improvement of code help to optimise the solution and to achieve the required outcomes.

• Selection

The ability to make discerning selections, helps students to choose a suitable problem-solving strategy for a given problem. They may select and apply one or more problem-solving strategies during program comprehension to help them to reach specific goals. For example, effective use of a top-down strategy demonstrates that a student has holistically conceptualised the entire program involving multiple classes, instances, and methods.

• Application

Finally and, in consolidation, the construction, reflection, and selection of knowledge, skills and strategies must be applied in OOP tasks to develop new programs and maintain existing ones. It is not the intention that every strategy should be applied in every situation. The various forms of knowledge, skills and strategies are relevant to different contexts. Learning to program is an active process of knowledge construction, reflection, and selection of appropriate activities to ensure successful programming.
Learning OOP requires a balanced approach of all the different activities involved. This implies, for example, that the application of Bloom’s skills without explicit reflection; or the application of strategies without any analysis, synthesis and evaluation skills will not support successful completion of a new program. In such cases, students must explicitly query the correctness of their own code and reflect on their prior thinking to identify the errors and to correct flaws.

5. CONCLUSION

To be successful in OOP, programmers require explicit learning both of programming content and higher-order mental activities. The findings of this research, which distinguishes between successful and unsuccessful programmers, indicate the need for a framework to support novice programmers. This should address programming subject matter as well as cognitive, metacognitive and problem-solving knowledge, skills and strategies. Fostering awareness and application of the latter among learners sets a particular challenge to educators (lecturers) to identify creative and effective means of doing so.

We propose a learning repertoire that includes knowledge, skills and strategies used by successful programmers. In order to apply this, various activities should occur during programming to meaningfully construct, explicitly reflect on, and critically select appropriate knowledge, skills and strategies to understand, design, code and test high quality programs. This involves the integration of specific cognitive, metacognitive and problem-solving techniques in a balanced manner. Although this framework focuses mainly on OOP, we believe that it can also be applied to support students in other programming paradigms, such as procedural programming. However, due to the particular complexities of OOP, the framework focuses specifically on a holistic view where various different decisions are required in programming one or more classes.

Future work will concentrate on the role of a lecturer or facilitator in the explicit teaching of the required knowledge, skills and strategies, supporting them in creating an educational environment in which the learning repertoire can be effectively applied. The development of assessment criteria to test the effective application of the activities of the learning repertoire in an OOP task should further support the students.

GLOSSARY

Novice: a person who is inexperienced and new in a particular field

Expert: a knowledgeable person with superior skills in a particular field

REFERENCES


Podcasts for Expansive Learning: A Case of Reflective Student Stories

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ABSTRACT
Most educational opportunities offered by mobile devices which are used by students for entertainment, such as iPods and mp3 players, have not been fully exploited. Although social uses of mobile devices among students is increasingly common, there has been little evidence to demonstrate how socially pervasive devices contribute to student learning. One of the phenomena changing the higher education landscape is podcasting. However, despite the growing adoption of podcasting in education, not much is known about effective integration of podcasts at pedagogical level to have meaningful impact on student learning. This paper reports on a two-year project that explored the use of podcasts to mediate reflection. The paper draws on expansive learning as espoused by Engestrom to illustrate how podcast mediated tasks escalated learning among students at a higher education institution. The paper analyzed students’ reflective stories using deconstruction analysis. The paper concludes that effective educational uses of podcasts require that learning activities are designed for reflection and podcasts used to scaffold the reflection process.

CATEGORIES AND SUBJECT DESCRIPTORS

GENERAL TERMS
Emerging Technologies, Deep Learning, Story-telling method

KEYWORDS
Podcasting; Expansive learning; reflective learning

1. INTRODUCTION
Anecdotal evidence shows that most students use portable devices for entertainment. Mobile devices are used for entertainment, iPods and mp3 players for listening to music and mobile phones for maintaining social networks. It therefore stands to reason that portable technologies are ubiquitous among students but these have not been fully exploited as teaching and learning tools. The convergence of entertainment devices, social practices, and emerging technologies provides useful teaching and learning opportunities. This paper focuses on one such opportunity, use of podcasts to scaffold expansive learning. Learning and reflection are like two sides of the same coin, as one cannot exist without the other. Accepting this argument, it follows that through scaffolding reflections; students can widen their perspectives on a given task and enrich their learning experience. Thus, reflection allows learning activities to continuously evolve and transform hence creating a dynamic learning process or an expansive learning process. Expansive learning is a method of grasping the essence of an object by tracing and reproducing theoretically the logic of its development, of its historical formation through the emergence and resolution of its inner contradictions [1]. It can be inferred from [1] that podcasts produce a way of grasping the essence of its (podcast) content engaging with the contextual underlying assumptions of the speaker and resolving the inner contradictions of the listener. To the extent that podcasts are one way communication (i.e. speaker to listener) both the subject matter (content) and the speaker’s audience assumptions are recipes of the listeners’ inner contradictions being continuously resolved during the listening process. Thus, augmenting reflective learning through design of learning tasks that scaffold students listening to podcasts has potential to lead to a deeper learning experience because of the sequence of epistemic actions evoked during the listening to podcasts.

An ideal-typical sequence of epistemic actions in an expansive learning cycle is described as follows [1]: The first action is that of questioning, criticizing, or rejecting some aspects of the accepted practice and existing wisdom. The second action is that

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1 Email: dick.ngambi@uct.ac.za
of analyzing the situation. Analysis involves mental, discursive, or practical transformation of the situation in order to find out causes or explanatory mechanisms. Analysis evokes “why?” questions and explanatory principles. The third action is that of modeling the newly found explanatory relationship in some publicly observable and transmittable medium. This means constructing an explicit, simplified model of the new idea that explains and offers a solution to the problematic situation. The fourth action is that of examining the model, running, operating, and experimenting on it in order to fully grasp its dynamics, potentials, and limitations. The fifth action is that of implementing the model, concretizing it by means of practical applications, enrichments, and conceptual extensions. The sixth and seventh actions are those of reflecting on and evaluating the process and consolidating its outcomes into a new, stable form or practice.

Expansive learning is an outcome of reflection as Engeström [2] put it succinctly:

…the new activity structure does not emerge out of the blue. It requires reflective analysis of the existing activity structure – one must learn to know and understand what one needs to transcend. And it requires reflective appropriation of existing culturally advanced models and tools that offer ways out of the internal contradictions.

It can be inferred from [2] that the challenge is learning to know and understanding what one needs to transcend when listening to podcasts. This challenge cannot be left to students and learning opportunities are missed if not scaffolding happen. The thesis of this paper is that podcasts are tools for reflection but do not by themselves guarantee reflection. There is therefore a need for reflective appropriation of podcasts within an expansive learning cycle if a user is to use podcasts as tools for resolving the emerging inner contradictions and have an enriched learning experience. To this end, podcasts are considered in the context of three interacting contexts of an expansive learning cycle [3]: criticism; discovery; and application. The context of criticism highlights the power of resisting, questioning, contradicting and debating. The context of discovery highlights the power of experimenting, modeling, symbolizing and generalizing. The context of application highlights the power of social relevance and embedness of knowledge, community involvement and guided practice. In all three contexts, reflection has the potential to benefit from podcasts. In particular questioning, contradicting and debating are reflective instruments that are either an outcome of reflection or prompt reflection. Questions can serve as prompts to enable a student to discover their own contradictions or misunderstandings. Podcasts can thus enable students to think deeper on their actions such as presentation style and confidence in responding to questions. Experimentation or modeling reflection is a post event activity and allows a person involved to think about the processes after the event. The social relevance and community involvement is critical as it underscores a need for learning communities in shaping reflections and for fostering knowledge creation. One way of achieving a learning community is through making student podcasts public to the class and designing tasks that require students to reference each others presentations. Podcasts have great potential for allowing students to articulate their understanding of ideas and concepts, and to share the outcome with the audience they value, such as their peers [4]. Students’ peer groups serve as supportive learning communities because in such groups students have a shared objective of coming together to collaborate and learn together [5]. Thus, the aim of this study was to explore how podcasts could be used to scaffold expansive learning for students’ learning communities.

2. PODCASTING OVERVIEW

The word podcast is a hybrid of ‘iPod’ and ‘broadcast’ and is a method of distributing audio files over the Internet using Really Simple Syndication (RSS feeds). RSS is commonly used for delivering summaries (feeds) of news stories. An RSS contains an index of items or episodes in the series, including title, date, description, and also specifies the multimedia enclosure (i.e. the link to the file, its size, and content type). The podcaster makes available the RSS feed which a user subscribes to using a podcatcher or an aggregator. Without subscription to an RSS feed, a user would download audio files from a website and play them using a media player. However, listening to podcasts through downloads requires that a user visits the sites where podcasts have been posted. In this regard, podcatchers take responsibility of checking for updates from all subscribed sites whereby allowing a user to ‘stay in one place’ while being notified about latest podcasts from subscribed sites. One of the reasons podcasting is having a major impact on education is the ability to make up-to-date content available immediately to large audiences via downloads or subscription-notification systems [6]. The caution here is that, like other technologies, podcasts not a panacea of all higher education challenges [7]. However, the potential of podcasts in education lie in the availability of easy to use free software such as Audacity1, which support both the generation and distribution of podcasts on the producer side, and tools for subscribing to podcasts and downloading them to mobile devices on the consumer side. Other reasons for the increasing popularity of podcasting is the increasing availability of tools that support easy production, hosting, distribution, subscription, automatic download and upload (to a mobile players) [8].

3. PODCASTS FOR EDUCATORS

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The number of institutions using podcasts, especially in the United States and the United Kingdom is growing. For example, Duke, Michigan, Purdue, Stanford, and UC Berkeley make podcasts of undergraduate lectures and publish them on the Web for enrolled students to access [11]. Publishing audio lectures is one of the common uses but not the only use. There are four ways in which podcasting will affect the education landscape [12]; firstly, podcasts will extend classroom learning beyond threaded discussion boards or physical class discussions; secondly, podcasts will be used by students to plan and prepare cooperative projects with peers; thirdly, throughout the semester students will use podcasts to extend, expand, or clarify virtual or physical

1 http://audacity.sourceforge.net/
classroom discussion; fourthly, students will listen to podcasts for extended professional community development. Pedagogical uses of podcasts are broadly classified in the areas of lecturing, tutoring, and remediation [6]. Some practical uses of podcasts include a student listening to a podcast during a bus ride to the university so as to refresh a lecture before meeting two of her friends to do their homework; three students doing homework together and one of them remembers a quote a teacher made during the lecture, they quickly look it up and listen to the respective part of the lecture [8]. James Hilton1, an Associate Provost at the University of Michigan has referred to podcasts as a technology poised to disrupt how higher education operates in a new knowledge economy. Others use podcasts to promote collaborative knowledge sharing through students having a shared task to script and create educational podcasts for their peers [4].

In the United Kingdom, the Informal Mobile Podcasting and Learning Adaptation Project (http://www.impala.ac.uk) has been exploring the use of podcasts in Higher Education since 2006. The IMPALA project has developed a podcast pedagogical model2. This paper takes the view that podcast mediated learning tasks fosters reflection and leads to expansive learning. The project reported in this paper, set out to answer the question: How do podcast mediated tasks scaffold expansive learning? In the quest to explore the question, a project was conceived at the University of Cape Town. The project ran for two years, in 2007 with 5 students and 2008 with 17 students.

4. METHODOLOGY

In this paper, an interpretive research approach is used. An interpretive paradigm is informed by a concern to understand the world as it is, to understand the fundamental nature of the social world at the level of subjective experience [13]. The social world was a community of 5 learners in 2007 and 17 in 2008. The 2007 course was used as a pilot. The focus of this paper is on the 2008 cohort. Learners were registered for a post graduate diploma course. None of the participants had used podcasts prior to coming on the course. Participants brought to the course varied experiential knowledge drawn from diverse contexts viz; primary, secondary, higher education, and government; discipline based experience from disability, health sciences, administration, and ICTs; ICT experience ranged from support services, networking, and systems administrator. Exposure to learning management systems was limited to proprietary systems. The significance of this was that student discussions were rich and students learnt from one another whereby fostering expansive learning.

Reflection was an integral part of the course and podcast mediated tasks were designed and integrated in learning activities. The course was organised as follows: Tuesdays (16:00 – 19:00) were dedicated to guest lecture presentations; and Thursday (16:00-19:00) were for student seminars. The three contexts of expansive learning were used as follows: Context of Criticism: during student seminars, individual students gave presentations on their understanding of an assigned article and peers asked questions which required spontaneous responses. The aim was to empower students to defend their positions and answer questions from peers; Context of Discovery: the post event activity required students to listen to the podcast of their presentation for self-critique and to reflect on their spontaneous handling of questions asked by peers. This involved reliving both their presentation and the presentation of others whereby learning from peers. Context of Application: to make the process of discovery worthwhile, students were required to write a two page reflective piece which had to be submitted for assessment.

The design of podcast mediated learning tasks was influenced by the Pedagogical Model proposed by the IMPALA project which postulate that good practice in using podcasting is to integrate podcasts in a learning management system (LMS) and to offer students 24/7 access to learning materials. As most of the students did not have 24/7 Internet access outside the University, the researcher was mindful of issues of access. The value of podcast is increased when podcast content supplement other learning activities. In view of this, a learning management system (Sakai3) was used in addition to podcasts mediated tasks. Needless to say, podcasts were distributed through the LMS. Tasks were derived from and linked to guest presentations students listened to in face-to-face sessions. Learning resources including podcasts were placed in the LMS from where students either downloaded to mobile devices or listened to from their desktops. Students engaged with assigned readings, attended guest presentations, and were assigned tasks that required them to reflect on the relations betwen theory and practice as espoused in the academic readings and guest lectures. The podcast mediated task was assigned to students after each student had given an oral presentation to the class, and engaged in a question and answer session with peers. The task on which this paper is premised is shown below:

Task 1: Write a short piece on your reflections of the course so far. Draw from the presentation you gave during the student seminar. (NB: Students had given presentations and answered questions from peers). Cite three people from the class and discuss how your reflections are impacted on by the reflections of your peers.

Students had narrated their reflections on the course thus far. A podcast of each reflection was generated. Podcasts were posted on the LMS. The task required that students cite at least three other students’ reflections. Thus the objective of the task was two fold: i) to allow students to reflect on how they presented and how they responded to questions from peers ii) to allow students to expand their views by taking into consideration the views of at least three other students. To accomplish the assigned task, students had at their disposal podcasts of their presentation and those of other students. Although it was not compulsory that students listen to peers’ podcasts, it would have been difficult to accomplish the task without listening to them. The deliverable of the task was a written text. All podcasts were designed for reuse and involved a single session in case of guest lectures and single sessions with multiple presentations as was the case for student seminars. Although student seminars had an informal feel to help students

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1 http://connect-cdn.educause.edu/files/active/0/E05-James_Hilton.mp3

2 http://www.impala.ac.uk/outputs/model.html

3 http://sakaiproject.org/
relax, discussions were serious. The class size remained the same at 17. The average class attendance during the semester was 15.

5. OBSERVATIONS

The research method of story was used to solicit students’ experiences of using podcasts. Story telling is a valid research method and in many respects could be compared to precedent cases used in the judicial system [8]. Just as in the courtroom, stories take the form of reflection in the presence of peers to make sense of their situation. Individuals, in a story telling process, retain a part of the story line, a bit of interpretation, story performance practices, and some facts that confirm a line of reasoning [8]. In this case, the story telling process is recursive as stories about student podcasting experience is also podcastrated, leading to a new podcasting experience. Podcasts were the third most used tool in the LMS during the semester under study (see Table 1).

### Table 1: Use of tools in the LMS

<table>
<thead>
<tr>
<th>Context of Application</th>
<th>Usage Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources / dropbox</td>
<td>87.4%</td>
</tr>
<tr>
<td>Forums / messages</td>
<td>5.2%</td>
</tr>
<tr>
<td>Podcasts</td>
<td>3.3%</td>
</tr>
<tr>
<td>Chatroom</td>
<td>1.7%</td>
</tr>
<tr>
<td>News</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

There were 17 stories, each narrating different ways students experienced tools used during the course. For the sake of brevity, extracts from five stories are analyzed. These stories were chosen as they represented voices that were echoed in different ways by other students. The discussed stories give insight into the relationship between task mediated podcasts, expansive learning and cognition. This is particularly important because expansive learning can only be inferred at cognitive level.

### 5.1 Deconstruction Analysis

In the following story, a student (who is also a school teacher) narrates her experience of listening to podcasts which were integrated into the learning process. She mentions that it was the first time to have listened to audio in that way. The task required that every student listen to their presentation paying special attention to how they answered questions from peers; and to listen to at least three other students and citing why chosen peer’s views were important.

**Story 1**: I have never used multimedia to playback a presentation session and to playback and write an assignment based on what I listened. Playing back several times peers’ reflections with an aim of selecting some for citation in this assignment was an experience I would value when I do my research work in the second year of this course.

In telling Story 1, the student appears to have gained so much interest in podcasting that she decided to pursue further research on the topic. This suggests that the context of discovery was created. Listening to a playback and writing an assignment is consistent with the context of application. As a consequence of having special focus on using podcasts to scaffold expansive learning, students told stories about subsidiary skills they acquired.

**Story 2**: One of the things I have learned is how to download a podcast onto a mobile phone. This can be done either using a data cable or via Bluetooth. I am quite familiar with downloading music and images from a computer using a data cable but I had no idea you could download voices as well. This is probably because I never made this connection: texts, images, sound (either as music or voice) and video are all data stored in different forms.

Of interest in Story 2 is that the student reflected on her prior skills on data transfer using Bluetooth but had not realised that the process of exchanging audio files were not different. This is a case of context of application having been realised. Another student explains how he learnt by listening to peer’s podcasts.

**Story 3**: As I listened to the podcasts, I realised that I too would learn a lot from the class because the sessions are all interactive. The importance of interaction in the learning experience should not be downplayed. Listening to the podcasts, I found myself agreeing with some of what my friends had said. At times I was thinking: “I totally agree with that” and at other times, I found myself thinking “That’s a different way of looking at the situation or I never thought of that!” Its amazing how one’s views can be coloured by those the people one interacts with.

The use of podcasts seems to have mediated expansive learning. This implies that there was a context of discovery. Story 3 tells of how his views were transformed through listening to peers’ podcasts. The internal conversation that occurred suggested that a context of criticism existed. In the next story, the student recalls how podcasts allowed him to revisit a lecture and engage with it.

**Story 4**: …the podcasts are more interesting and easy to use in diverse socio-economic situations because they can be used in different ways. And to learn that learners revisit a previous lesson and critically engage with the lesson afterwards was quite exciting to me. I could not believe until I had an opportunity to download some podcasts from the internet and listened to them. I was able to follow the seminar in a deep and critical way than the seminar time.

The significance of Story 4 lay in the way the student saw the application of podcasts to serve the needs of students from diverse socio-economic backgrounds (i.e. context of application). The critical engagement with a lesson in the absence of the lecturer or peers suggests that a safe context of criticism was created. The disbelief and subsequent positive experience testifies to a context of discovery having existed. The final story to be considered is one where a student saw possibilities of podcasts beyond the experiences exposed to in class.

**Story 5**: What she said actually made me realize that OBE5 can greatly benefit from the use of ICTs. Podcast is the best tool for OBE. It can help learners to reflect on their participation during group work and project making. It is a good tool to use for groups to give each other feedback during class debates. It is learner friendly.

In this story the student expanded her imagination having listened to podcasts from peers. The student adds that podcasts could be useful for group feedback. This suggests there was a context of discovery. To the extent that the story goes further to

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5 Outcome Based Education
mention OBE as a possible application area of podcasts is evidence that a context of application was created.

6. DISCUSSION AND CONCLUSION

The research question that premised the study is revisited with the view to determining the extent to which it has been answered. The question sought to investigate how podcast mediated tasks can scaffold expansive learning. The analyses of student stories show that the three interrelated contexts of expansive learning viz. the context of criticism, context of discovery, and the context of application were mediated through podcasts. The learning community involved 17 students who had respect for each others views and had a shared objective which fostered a sense of purpose for the group. The learning tasks were designed to allow individual students to reflect on their learning and listen to both their own podcasts as well as other students’. While each student was focused on their individual learning, each contributed to community knowledge and drew from it. This finding is consistent with [10] who report the need to destigmatising collaboration and argue that finding out from or gaining advice from other people or to use information from other sources not already in ones head, was not cheating. This view on collaborative learning is supported by the observation that students learnt from creating and sharing podcasts with an audience they valued such as their peers [4].

It is worth noting that although students had opportunities to ask peers questions during face-to-face sessions, some questions or comments for presenters arose when listening to podcasts (as is the case in Story 3). Sometimes the student would agree or disagree with the presenter while listening to a podcast. This post presentation engagement suggests two things: i) the context of criticism extended beyond time and space of a traditional classroom; ii) the needs of slow learners or struggling students who need more time to understand or follow a discussion before they can engage or make a contribution were served. It follows that podcasts scaffolded expansive learning beyond the limitations of traditional classrooms.

This paper has described the phenomenon of podcasting, its general uses in higher education, pedagogical models of using podcasts; has shown how devices students use for entertainment are being recast for educational uses; has illustrated pedagogically how expansive learning can be scaffolded; demonstrated use of reflective story telling as a teaching strategy; augmented story telling with reflective learning; and illustrated ways that podcasts can be used to scaffold expansive learning. The conclusion is that podcast mediated reflective learning can scaffold expansive learning. However, podcast mediated tasks need to be designed if podcasts are to have any meaningful impact on teaching and learning.

REFERENCES

The International Visibility of South African IS Research: An Author-Affiliation Analysis in the Top-Ranked IS-Centric Journals

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ABSTRACT
Information systems (IS) has a well-known tradition of being multi-disciplinary. IS research has been published in a diversity of outlets. As the discipline has evolved, there have been several scientometric studies aimed at identifying and ranking a core set of high quality IS-centric journals. This effort has spawned additional investigations aimed at profiling IS research in different regions and countries across the globe. The purpose of this study is to add to the body of knowledge in this domain by investigating the international visibility of South African IS research. The scope of the study was limited to investigating journal publications. The approach used was to identify from the literature a basket of IS-centric journals ranked as the top set in the field. The affiliations of authors in these journals for the period 2003 to 2007 were examined, and South African-authored publications identified. The analysis revealed that South African-affiliated authors have published in only a small portion of these IS-centric journals. The total number of articles published has also been small. These findings may explain why South African IS research has been perceived as largely unknown by the international IS academic community. This is despite numerous publications in outlets outside of the commonly ranked IS-centric journal set. If South African IS researchers are to increase international visibility, one strategy is to explicitly target the commonly accepted top-ranked IS-centric journals. Other strategies for achieving this are proffered in this paper, and ideas for future research are put forward.

CATEGORIES AND SUBJECT DESCRIPTORS
K.3.2 [Computers and Information Science Education]

GENERAL TERMS
Management, Human Factors, Theory

KEYWORDS
International visibility; Journal quality; Journal Ranking; South Africa. Information Systems Discipline

1. INTRODUCTION
The Information Systems (IS) discipline has been aptly described as a fragmented adhocracy [1]. Debates on the identity crisis within Information Systems have been ongoing for several decades now [2]. Given its multidisciplinary nature, research in the field is conducted using a diverse set of research methodologies ranging from positivist to interpretivist to critical [10]. This has lead to publication of IS research within a diversity of journal outlets. Apart from essentially IS-centric journals, these also include journals from related disciplines such as computer science, information and library science, organization science and operations research.

As the discipline has matured, research has begun to focus on publication patterns and quality of outlets for IS research [7]. Lowry et al. [8] state that “where and how we publish are fundamental aspects of the identity of the IS field—reflecting our value systems, paradigms, cultural practices, reward systems, political hierarchy, and aspirations” (p. 1). The ISWorld website provides a comprehensive list of scientometric studies that have attempted to establish journal rankings [12]. Additional scientometric studies have been conducted to assess researcher productivity [5]. For instance, Galliers & Whitley [4] investigated the profile of European IS research, while Sellito [13] examined journal publication diversity in Australia. Not much is known about the international profile of South African IS research.

The purpose of this paper is to add to the body of knowledge in this domain by investigating the international visibility of South African IS research. International visibility is defined in

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the paper as the extent to which authors affiliated with South African institutions publish in highly-ranked IS journals.

In the next section, alternative journal rankings are investigated before a list is chosen that is to be used in this study. A short background is provided on the context of South African IS research, and the research methodology is explained. The data analysis and results are laid out before these are discussed and implications drawn. Limitation and future research are outlined and the paper is then concluded.

2. JOURNAL RANKINGS

With well over 600+ journals publishing IS-related research [6], choosing an outlet in which to publish has become quite daunting for researchers. Many research institutions rightfully expect that faculty should produce quality research and publish it in prestigious, high quality journal outlets. Determining journal prestige, then, has become an area of concern in most disciplines, including IS. Several IS journal ranking studies have been reported over the past decade [12]. These have varied from all-inclusive studies which have included in rankings such non-peer-reviewed outlets as PC Magazine, to ones that have examined only peer-reviewed academic journals [8]. Various approaches to ranking have also been employed including surveys of researchers [8], IS school ranking lists [7], and author affiliation indices [3].

Determining the basket of journals to use has not been easily resolved [7]. For example, decisions have to be made as to whether to include journals from related disciplines such as Management Science and Decision Sciences. Although not pure IS journals, these outlets publish IS research on a regular basis. As the discipline matures, there have been calls for identifying and ranking a list of high-quality IS-centric journals. Peffers & Tang [11] in attempting to resolve this dilemma, identified over 300 journals deemed to be IS-centric, and through a survey of IS researchers established a basket of top 50 journals. There have not been many other studies attempting to do this, and as such, the basket provided by Peffers & Tang [11] has since been used in other studies wanting to assess IS-centric journals [7].

3. SOUTH AFRICAN IS RESEARCH CONTEXT

The South African IS research community is small when compared to many developed countries. Furthermore, unlike in many developed countries there are no purely IS-centric South African journals. ICT-related journals that do exist typically serve the wider ICT/Computing community (e.g., South African Computer Journal). Other local outlets for IS research include multidisciplinary social science journals (e.g., Alternation) and business management journals (e.g., South African Journal of Business Management) among others. This may imply that a strong IS research community is yet to be established in South Africa.

In order to assess the status of researchers and allocate resources, the South African National Research Foundation (NRF) encourages researchers to apply for rating. Three major rating categories are A-rating (Leading international researcher), B-rating (Internationally acclaimed researcher), and C-rating (Established researcher) [9]. It is instructive to review the statistics around these ratings. Given the multidisciplinary nature of IS, it is difficult to establish the exact number of rated researchers who espouse allegiance to the IS discipline. The broader ICT/Computing community encompasses Computer Science, Educational Technology, Information Systems and Information Science researchers. Table 1 below shows the approximate numbers of NRF-rated researchers who have as their primary research interest some aspect of ICT/Computing (e.g., Computer Science, Information Systems, Information Science, Information Technology, Education and Educational Technology, etc.). Data was drawn from the NRF website, which shows that there were 1698 rated researchers in South Africa in 2007 [9].

<table>
<thead>
<tr>
<th>Rating Category</th>
<th>Approximate No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Leading International)</td>
<td>0</td>
</tr>
<tr>
<td>B (Internationally Acclaimed)</td>
<td>6</td>
</tr>
<tr>
<td>C (Established)</td>
<td>35</td>
</tr>
<tr>
<td>L (Late Entrant into Research)</td>
<td>3</td>
</tr>
<tr>
<td>P/Y (Promising Young Researcher)</td>
<td>8</td>
</tr>
</tbody>
</table>

The approximately 52 rated ICT researchers represent about 3% of the total number. It is noticeable that there are no leading international researchers in the ICT field. Suffice to say, there may be leading international researchers in other disciplines who at times conduct research which could be described as within the field of ICT. Six internationally acclaimed ICT researchers were found. The small number of internationally acclaimed researchers may be an indicator of the level of international visibility of the South African ICT research community. Indeed the small number of rated researchers as a whole attests to the small size of the community. IS researchers form an even smaller part of this group. This small group, together with other researchers whom for whatever reason are not rated, manage to publish in international journals. The international visibility of their research will be investigated in this paper.

4. RESEARCH METHODOLOGY

The purpose of this paper is to investigate the international visibility of South African IS researchers. Therefore, an exploratory approach has been adopted, using journal publication data. IS-centric journals were chosen for examination, since visibility of South African IS research amongst global IS scholars was being investigated. Examining all possible outlets for IS research was beyond the scope of the paper, as this would have entailed an analysis of over 600 journals. It is argued in this paper that international visibility is best assessed by investigating the generally accepted top research outlets in the field. The top 50 IS-centric journals identified by Lewis et al. [7] were selected as the basket of journals to examine (see Appendix 1). Rankings were determined by aggregating IS school lists [7]. Lewis et al. [7] based their IS-centric journals list on the one provided by Peffers & Tang [11] with some minor modifications.

The approach used for gathering data was to peruse articles within the top 50 IS-centric journals published over the past 5 years (2003 to 2007) in order to ascertain the more recent status of international visibility. Articles that were written by authors affiliated to South African institutions were identified in these journals, and the data collated.

Upon encountering a South African affiliated author, the journal article was downloaded and the authors’ names, specific affiliations, and year of publication were recorded. The number of articles published for each year between 2003 and 2007 were cumulated as well as the total number of articles published per research institution. References for each relevant article were
recorded and were later used to categorize the articles into their respective research themes.

Table 2: South African author-affiliated articles

5. DATA ANALYSIS AND RESULTS

Table 2 shows that 19 of the top 50 IS-centric journals contained publications by authors affiliated to South African institutions (see Appendix 2 for article details). The journals with the most South African-authored articles were the International Journal of Information Management (9 articles), followed by the Journal of IT Education and Informing Science (8 articles) and the Journal of Information Management (6 articles). The Journal of IS in Development (5 articles) and the Journal of the AIS (4 articles) were also significant contributors. The total number of articles affiliated with South African institutions across all journals was 19.

<table>
<thead>
<tr>
<th>Journal</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int. Jnl. of Info. Mgt.</td>
<td>3</td>
</tr>
<tr>
<td>Jnl. of IT Education</td>
<td>4</td>
</tr>
<tr>
<td>Informing Science</td>
<td>5</td>
</tr>
<tr>
<td>MIS Quarterly</td>
<td>6</td>
</tr>
<tr>
<td>Decn. Support Systems</td>
<td>7</td>
</tr>
<tr>
<td>Info. Resource Mgt. Jnl.</td>
<td>8</td>
</tr>
<tr>
<td>Behavior &amp; IT</td>
<td>9</td>
</tr>
<tr>
<td>Info. Systems Mgt.</td>
<td>10</td>
</tr>
<tr>
<td>Info. Research</td>
<td>11</td>
</tr>
<tr>
<td>Info. &amp; Mgt.</td>
<td>12</td>
</tr>
<tr>
<td>The Info. Society</td>
<td>13</td>
</tr>
<tr>
<td>Int. Jnl. Of HC Studies</td>
<td>14</td>
</tr>
<tr>
<td>Comm. Of the AIS</td>
<td>15</td>
</tr>
<tr>
<td>Jnl. of Computer IS</td>
<td>16</td>
</tr>
<tr>
<td>Jnl. of Glob. Info. Mgt.</td>
<td>17</td>
</tr>
<tr>
<td>Jnl. of Glob. IT Mgt.</td>
<td>18</td>
</tr>
<tr>
<td>Info. Processing &amp; Mgt.</td>
<td>19</td>
</tr>
<tr>
<td>Jnl. of IS Education</td>
<td>20</td>
</tr>
<tr>
<td>TOTAL</td>
<td>21</td>
</tr>
</tbody>
</table>

In comparing the rank of the 19 journals containing South African-authored research with the 31 that did not, there were no major differences. One discernible trend was the tendency for South African authors to target international or global journals (e.g., International Journal of Information Management, Journal of Global Information Management). The research agenda for such journals is generally receptive to perspectives from countries across the globe, which makes it possible to publish research concerning the local South African context in these outlets.

Further searches for IS research published by authors affiliated with South African institutions revealed that just as many, if not more articles were published outside of the top 50 ranked IS-centric journals. Outlets targeted included the Electronic Journal of IS Evaluation, Computers & Security, Computers & Education, Telecommunications Policy and the Electronic Library among others. This may be indicative of the South African research publication environment whereby the Department of Education (DoE) recognizes international journals listed on the Thomson ISI and the IBSS (International Bibliography of the Social Sciences) indices. These journals may then be the targets for publication rather than ranked journal lists such as in Appendix 1. Very often there is an overlap. Journals both highly ranked and indexed in ISI and/or IBSS should be the prime targets for South African IS researchers. Another reason for South African researchers not specifically targeting the top 50 may be that in developing countries such as South Africa, research focused on IS and national development is pertinent. As such, South African researchers may direct their research of this nature to journals with the same focus. To ascertain whether this holds a selection of 3 journals having a development focus were analysed as shown in Table 3. Table 3 shows that in these journals, 11 articles were published by researchers affiliated with South African institutions in the period 2003 to 2007.

Table 3: Development-oriented IS journals

<table>
<thead>
<tr>
<th>Other IS-Centric Journals</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jnl. of Comm. Informatics</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>IT for Development</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Elec. Jnl. of IS in Dev. Count.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Articles were also analyzed by university to assess any trends towards targeting IS-centric journals. Figure 1 shows that amongst South African universities, authors affiliated with the University of Cape Town [UCT] appear most often in the top-ranked IS-centric journals (14), followed by authors affiliated with Witwatersrand University [Wits] (7), University of Pretoria [UP] (5), and University of Johannesburg [UJ] and University of South Africa [UNISA] (3 each). Cape Peninsula University of Technology [CPUT], and University of the North West [UNW] followed (2 each), and then Nelson Mandela Metropolitan University [NMMU], University of Zululand [UZ] and University of the Western Cape [UWC] (1 each). Given the small number of publications, the accidental exclusion of even 1 publication becomes very apparent. This highlights how little research emanating from South African-affiliated authors has been published in these journals.
Table 4 shows that articles in the highest ranked journal were from UNW and UWC (each had one article in MIS Quarterly). Authors affiliated with UCT and UJ respectively had an article in the 6th highest-ranked journal (Decision Support Systems). Authors affiliated with Wits had an article in the 16th-ranked journal (The Information Society).

Table 4: Publications per University and Journal Rank for 2003-2007

<table>
<thead>
<tr>
<th>Journal</th>
<th>Rank</th>
<th>Uni.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journal of IT Education</td>
<td>44</td>
<td>UCT</td>
</tr>
<tr>
<td>Int. Jnl. of Information Mgt.</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>Information Resource Mgt. Journal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communications of the AIS</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>Decision Support Systems</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Informing Science</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Int. Jnl. of Human Computer Studies</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>Jnl. of Computer Information Systems</td>
<td>26</td>
<td>1</td>
</tr>
<tr>
<td>Jnl. of Global Information Mgt.</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Jnl. of Global IT Mgt.</td>
<td>34</td>
<td>1</td>
</tr>
<tr>
<td>Behavior &amp; IT</td>
<td>27</td>
<td>2</td>
</tr>
<tr>
<td>Informing Science</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>Int. Jnl. of Information Mgt.</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>The Information Society</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Int. Jnl. of Information Mgt.</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>e-Service Journal</td>
<td>46</td>
<td>1</td>
</tr>
<tr>
<td>Information Systems Mgt.</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>Journal of IS Education</td>
<td>39</td>
<td>1</td>
</tr>
<tr>
<td>Information Systems Mgt.</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>Information Research</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Int. Jnl. of Information Mgt.</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>Journal of IT Education</td>
<td>44</td>
<td>1</td>
</tr>
</tbody>
</table>

The articles found were analyzed to identify common themes. 7 major themes were defined, these being IS Management and Knowledge Management (10 articles), IS and National Development (8), Education and Research (6), IS Projects and Systems Development (4), Web and e-Commerce (4), Decision Making (3), Mobile Applications (3) (see Table 5 below). It is acknowledged that alternative classifications could have been used, but the above were deemed as adequate for the analysis in this paper. The institutional affiliation of South African-based authors is indicated in square brackets at the end of each reference in Table 5 (See Appendix 2 for full details).

Table 5: Publications by Themes

<table>
<thead>
<tr>
<th>Theme</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS Management &amp; Knowledge Management</td>
<td>Brown (2004) [UCT].</td>
</tr>
<tr>
<td></td>
<td>Brown &amp; Russell (2007) [UCT].</td>
</tr>
<tr>
<td></td>
<td>Cohen &amp; Toleman (2006) [Wits].</td>
</tr>
<tr>
<td></td>
<td>Da Veiga &amp; Eloff (2007) [UP].</td>
</tr>
<tr>
<td></td>
<td>du Plessis (2005) [UP].</td>
</tr>
<tr>
<td></td>
<td>du Plessis &amp; Boom (2004) [UP].</td>
</tr>
<tr>
<td></td>
<td>du Toit (2003) [UJ].</td>
</tr>
<tr>
<td></td>
<td>Hart &amp; Porter (2004) [UCT].</td>
</tr>
<tr>
<td></td>
<td>Pretorius &amp; Barnard (2004) [UNISA].</td>
</tr>
<tr>
<td>IS &amp; National Development</td>
<td>Braa et al. (2007) [UWC].</td>
</tr>
<tr>
<td></td>
<td>Brown et al. (2007) [UCT].</td>
</tr>
<tr>
<td></td>
<td>Introna &amp; Whittaker (2006) [Wits].</td>
</tr>
<tr>
<td></td>
<td>Meyer (2005) [UNISA].</td>
</tr>
<tr>
<td></td>
<td>Onyancha &amp; Ocholla (2005) [UZ].</td>
</tr>
<tr>
<td></td>
<td>Rhodes (2003) [UCT].</td>
</tr>
<tr>
<td></td>
<td>Thatcher et al. (2007) [Wits].</td>
</tr>
<tr>
<td>Education &amp; Research</td>
<td>De Villiers (2007) [UNISA].</td>
</tr>
<tr>
<td></td>
<td>Hart (2006) [UCT].</td>
</tr>
<tr>
<td></td>
<td>Lynch et al. (2007) [UCT].</td>
</tr>
<tr>
<td></td>
<td>Mende (2005) [Wits].</td>
</tr>
<tr>
<td></td>
<td>Napier &amp; Johnson (2007) [UP].</td>
</tr>
<tr>
<td></td>
<td>Scott et al. (2004) [UCT].</td>
</tr>
<tr>
<td>IS Projects &amp; Systems Development</td>
<td>Cuellar et al. (2006) [UP].</td>
</tr>
<tr>
<td></td>
<td>Huisman &amp; Ivvari (2006) [UNW].</td>
</tr>
<tr>
<td></td>
<td>Ivvari &amp; Huisman (2007) [UNW].</td>
</tr>
<tr>
<td></td>
<td>Sewchurran &amp; Petkov (2007) [UCT].</td>
</tr>
</tbody>
</table>

6. LIMITATIONS AND FUTURE RESEARCH

There were several limitations in the study. In the first instance, very little research has been conducted to identify a broadly
accepted list of top-ranked IS-centric research. The list provided by Lewis et al. [11], based on Peffers & Tang [7] is a start in this direction. The list, however, still contains journals that are not purely IS-centric. Several journals on the list can be better described as multidisciplinary (e.g., International Journal of Information Management, Decision Support Systems, etc.).

Given the large number of journals to be searched, and the very few South African-affiliated papers found, it may be that some South African-affiliated publications could have been omitted. To reduce the probability of this happening, both authors were involved in searching for articles.

It was found that a large number of articles by South African-affiliated researchers have been published in international journals outside of the top-ranked 50. Future research might examine a comprehensive set of these to obtain a holistic view of international visibility. In addition, the most prestigious IS conferences might be analysed to establish the holistic view of international visibility. In addition, the most prestigious IS conferences might be analysed to establish the level of international visibility of South African authors in this set. Another interesting area of study would be to investigate the extent to which South African IS researchers are publishing in journals focusing on issues pertaining to developing countries.

7. CONCLUSION

The IS research community in South Africa is small. This small size has a major influence on the international visibility of South African IS research. The analysis has revealed that between 2003 and 2007 authors affiliated with South African institutions published in just under 40% of the 50 top-ranked IS-centric journals. In addition, only 39 articles were published in this set. Much more research has been published outside of the top 50 IS-centric journals. This may be as a result of the South African Department of Education policy which recognizes international journals listed on the ISI and IBSS indices. South African IS researchers may target these general journal lists, rather than IS-centric ranking lists such as those proffered by Lewis et al. [7], and on the ISWorld website [12].

In the most prestigious journals (e.g. MIS Quarterly), South African authors have typically published in collaboration with international scholars. This trend has been noted too in Australia [13]. It is perhaps a strategy that can be employed by South African IS researchers as they strive to make an impact at the highest level of published research. Another strategy is to publish with South African researchers from other related disciplines who are known as international leaders in their field.

The journal which most often publishes research from authors affiliated with South African institutions is the International Journal of Information Management. Explicitly international and global journals have an appreciation of perspectives from diverse regions and cultures, and may be the specific target of South African researchers. Journals concerned with IS and national development were also found to be the targets of South African research, given that their research agenda aligns very well with that of developing countries. Many of these development-oriented journals, however, do not feature amongst the top-ranked IS-centric journals. This may be another reason for the relatively low international visibility of South African IS research. Many of the journals that rank highly in IS may not be suited for much of the development-oriented South African IS research. As a result, only a small subset of top-ranked journals is regularly targeted. A large number of other journals deemed to be more appropriate outlets are also targeted. This affects the international visibility of South African IS research. In order to improve visibility, South African IS researchers will have to devise strategies to increase publications in the top-ranked IS-centric journals, while continuing at the same time to publish in journals more suited for development-oriented research. The findings of this study will be of direct benefit to South African IS researchers wishing to apply for NRF rating, or wishing to improve their ratings.

REFERENCES


APPENDIX 1: TOP 50 IS-CENTRIC JOURNALS [7]

<table>
<thead>
<tr>
<th>Journal</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIS Quarterly</td>
<td>1</td>
</tr>
</tbody>
</table>

SACJ, No 42., 2008
### APPENDIX 2: PUBLICATIONS BY THEMES – REFERENCE LIST

#### IS management and knowledge management


#### IS and national development


Education and research


IS projects and systems development


Web and e-commerce


Mobile applications


Decision making


An In-Depth View of MCQ-based Testing in Information Systems

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University of the Witwatersrand, Johannesburg, Private Bag X3, WITS, 2050.

ABSTRACT
To cope with growing student numbers and high faculty-to-student ratios, most introductory Information Systems courses use Multiple Choice Questions (MCQ) to examine large parts of the curriculum. An in-depth review of first year Information Systems examination papers across five South African universities revealed that the majority of these MCQ question papers test student recall of factual knowledge, with only a few questions going to the deeper level of conceptual understanding OR application. This paper further reports on work done towards developing MCQ’s that allow for both the development and assessment of deeper levels of cognitive ability (as defined in Bloom’s Taxonomy). Results suggest that carefully constructed MCQ’s have the potential to enable valid and reliable assessment of depth of understanding by information systems students whilst supporting manageability through automated marking.

CATEGORIES AND SUBJECT DESCRIPTORS
K.3.2 [Computer and Information Science Education]: Information Systems Education

GENERAL TERMS
Verification.

KEYWORDS
Assessment, education, Bloom, multiple choice questions

1. INTRODUCTION
In common with the majority of both regional (South and Southern African) and international tertiary institutions, our academic staff are faced with the reality of growing student numbers in introductory Information Systems courses, without similar growth in resources, resulting in higher faculty-to-student ratios and an increasing administrative burden in coping with the larger student numbers. In fact, virtually all of the South African universities who participated in the comparative aspect of this study report one or more vacancies for academic staff alone. Furthermore, in common with first year classes internationally (and across most disciplines) the increase in student numbers brings with it an increase in the diversity of students in a class, in terms of ability, background and preparedness for tertiary education, and motivation [6]. In addition, as Biggs [2] points out, classes contain fewer of the traditional “academic” university student looking for an education, and a far greater percentage of the new style student who is looking for a qualification and ultimately a job.

In this paper we position and examine one aspect of a broader study entitled “Assessment for Learning: a case study of higher education students’ access to evaluative criteria” which has been undertaken in order to improve teaching and learning across the university. Placing assessment firmly centre-stage, the study examines the assessment processes in three introductory, large class courses in three different faculties, taken by the majority of students within a particular faculty or degree programme. It comprises a multi-disciplinary research team, led by the Division of Curriculum Studies in the School of Education, with discipline specialists drawn from within the academic staff of the various disciplines at the University of the Witwatersrand, Johannesburg.

The aim of the project is to investigate how assessment practices can help students to better demonstrate their learning through their response to evaluative criteria.

The approach taken in the broader study was to establish a baseline through the examination of lecturers’ understanding of student learning in their discipline, assessment tasks, and the corresponding student responses and marks. These are examined in terms of broad frameworks, Bloom’s revised taxonomy for assessment tasks [1], and Biggs’ SOLO Taxonomy for student responses or answers [5], with more detailed examination for specific types of assessment tasks drawing on the specialised assessment literature relating to those types of tasks. Thereafter, focused interventions are undertaken with academics in these disciplines in order to design and implement assessment strategies focused on supporting teaching and learning in these courses. The lessons learned will enable similar strategies to be implemented in other
first year courses, as well as other years of study across the university.

2. PROBLEM STATEMENT, OBJECTIVES AND RESEARCH QUESTIONS

During the initial baseline examination of assessment tasks and practices in the broader research study discussed above, MCQs and similar types of short answer questions were identified as comprising a very high proportion of the summative assessment tasks of the course. Furthermore, both the MCQs and other questions were generally found to be testing low levels of cognitive ability, and largely focused on factual, rather than conceptual or procedural knowledge.

Recognising the constraints imposed by student numbers and resources shortages, the objective in the research presented in this paper was to investigate ways in which to capitalise on the benefits of using MCQs (reliability, test automation, detailed and very quick feedback, etc.) while overcoming issues such as low validity and lack of discrimination between performances of poor, average and good students.

In this paper we accept that the use of MCQs in timed examinations is a strategic response to the challenges posed by large classes and limited resources, but argue that carefully constructed MCQs can support both reliable and valid assessment, requiring students to demonstrate high levels of cognitive engagement with factual, procedural and conceptual knowledge.

This prompted the following research questions:

Research Question 1
To what extent are MCQ questions being used in the assessment of higher level cognitive engagement with knowledge in the foundation information systems courses of South African tertiary institutions?

Research Question 2
Is it possible to design MCQs that assess students at deeper levels of cognitive ability?

Research Question 3
Is it possible for MCQ questions to distinguish between those students who have constructed conceptual relationships between concepts in the field (high level cognitive ability) and those who have only been capable of memorizing isolated facts (low level cognitive ability)?

3. LITERATURE SURVEY

Assessment is a complex and multifaceted aspect of all teaching and learning undertakings. While often viewed or interpreted very narrowly by the participants or users, it takes on many forms and is undertaken for many different purposes. The many purposes of assessment may be summarised as: allowing for judgement to be made in terms of mastery or achievement (for certification, selection, progression, etc.); to provide feedback to teachers or students relating to progress or understanding; and to satisfy external parties in terms of quality assurance [2, 3, 4, 7, 10, 11], to name but a few.

Regardless of its intended role (summative judgement, formative feedback to students or faculty, diagnostic, selection, etc.) assessment is viewed by the majority of students as defining the real or actual curriculum, rather than the carefully worded course outcomes and objectives.

“From our students’ point of view, assessment always defines the actual curriculum. In the last analysis, that is where the content lies for them, not in lists of topics or objectives. Assessment sends messages about the standard and amount of work required, and what aspects of the syllabus are most important” Ramsden [10].

To the student, the assessment tasks and criteria signal what academics value, or as Rowntree [11] expresses it “what the system requires students to do to survive and prosper”. This holds true for both students who simply want or need to pass the course (the “new style student”), as well as for those hoping to do well, the more traditional or academic student.

Assessment therefore tends to determine what the student learns (“is this in the exam?”), what the student does (“does this count for marks?”), how the content is learnt or covered (memorisation of facts versus attempts to construct conceptual frameworks with relationships, etc.) and the degree to which the knowledge (or set of isolated facts) is retained and usable by students (application, generalisation and further development).

Termed by Biggs [2] as the “backwash” effect, the above suggests that assessment needs to be carefully constructed to achieve the desired educational outcomes or objectives as envisioned by the academics teaching the course. If, for example, it is key that students develop the ability to analyse or synthesise particular concepts in a field, then assessment tasks must require students to be able to analyse and synthesise those concepts, not simply recall or explain them.

Furthermore, Biggs [2], suggests that the assessment approach or task tends to influence greatly the learning approach that will be adopted by students “in handling” learning tasks. Students using a surface learning approach tend to focus on indications of learning or knowledge, such as terms or facts, and use these in isolation or independently of each other, while students using a deeper approach attempt to focus on understanding the main ideas, concepts, principles and relationships. While he believes that most students demonstrate a preference for approach, the teaching and learning context, especially assessment, can influence their actual approach in practice.

3.1 Assessment Imperatives

Central too, to discussions on assessment practices and strategies, are careful consideration of the issues of assessment validity, reliability and manageability.

Validity, as in other contexts, looks at the degree to which an assessment task or question is a valid means by which to judge achievement of a required learning outcome or objective. If, for example, it is important for a student to be able to apply a procedure to a new situation, it would not be possible to make a valid judgement on whether or not they were able to do that, by asking them to list the steps involved in the procedure.

Reliability, again as in other situations, looks at the degree to which we could confidently predict the same result or outcome based on the sample provided by the assessment tasks or questions. Would all assessors make the same judgement of the student’s ability independently? Would a student either passing or failing the task be likely to have achieved the same result on another task testing the same ability or knowledge?

Manageability of assessment tasks or strategies, looks at amongst other issues, how usable and affordable the assessment tasks are [6, 7]. Do the tasks provide useful and meaningful feedback and “feedout” (in the case of summative assessment)? Are the resources available in terms of time, manpower and facilities?
3.2 Using MCQs as a Strategy for Assessing Large Classes

One of the major issues driving this research project, and shared by all the universities considered in the comparative analysis in this research, is that of large classes and tight resources.

Brown [3] suggests several strategies for large class assessment, including reducing the assessment load and the delegation of marking. Within these strategies are the suggestions to use ICTs, and to produce assessment tasks that allow for relatively easy marking while maintaining reliability.

Multiple Choice Questions are frequently used in courses with large numbers and broad curricula as a strategic means by which to assess. In our research alone, all the universities use MCQs to test the majority of the course content in final summative examinations.

MCQs have many positive aspects, including high reliability, high manageability in terms of ease of marking (through delegation or automation), ease of use in implementation (automation and availability of questions from textbook test banks), as well as immediate and detailed feedback to lecturers and students.

On the negative side, most MCQs appear to be set at low levels of cognitive demand, especially those drawn from textbook test banks and they may be time-consuming to set if well constructed and unambiguous. Biggs [2] also comments that exclusive use of MCQs “greatly misleads” students in terms of “the nature of knowledge”, with all ideas, whether detailed facts or overarching concepts or principles reduced to the same value or mark. He cites Lohman [8], “there is no need to assemble these ideas into a coherent summary or to integrate them with anything else because that is not required.”

In this research we suggest that well constructed MCQs can both capitalise on the recognised positive aspects associated with their use, as well as overcome the some of the negative ones, thereby validating their use as a strategic response to large class assessment.

4. RESEARCH METHODOLOGY

Two phases were needed to answer this paper’s three research questions. The first phase of the study involved a process of auditing MCQ assessment practices used in foundation IS courses. The second part of the study aimed to explore ways in which MCQs can be used to test application, analysis and even evaluation of conceptual and procedural knowledge.

4.1 Phase 1 - Data Collection

The first phase of the study addressed research question 1. The phase involved an evaluation of past examination papers of five tertiary institutions in South Africa. The examination papers were all used in the summative assessment of students in the foundation (first year) information systems / informatics course, and all employed the use of multiple choice questions. A request was sent to SACLA members to share their past papers with the authors for the purposes of this analysis. Five institutions responded and a total of 231 unique MCQ questions were reviewed by the authors. Each question was classified into the relevant cells of the matrix (see Table 1). The matrix is based on the work of Anderson [1].

4.2 Phase 1 - Data Analysis

The findings reveal that 74% of the questions demand little more than the recall of factual knowledge presented in a typical introductory textbook, with 81% in total at the cognitive recall level (Figure 1). 12% of the questions are at the comprehension level, requiring students to demonstrate comprehension of factual or conceptual knowledge. Such questions were usually achieved by requiring students to interpret data/facts or correctly identify the use of a concept in an example not previously seen. Such questions require students to have understood what they’ve learned and translate that knowledge into a new context [13].

Remarkably, just over 6% of questions tapped into the application and analysis levels, which according to Woodford and Bancroft [13] should require students to solve problems by applying knowledge, facts, techniques and rules (application) or examining information, breaking it into parts, identifying patterns, causes, relationships, analyzing effects and making inferences (analysis).

It is also worth noting that the majority of application level MCQ questions involved the application of programming / software application rules or formulae as opposed to the application of management information systems principles.

Interestingly, all questions, regardless of cognitive demand, carried the same mark weighting. Not only does this practice fail to consider the time requirements of higher level questions, but most importantly this practice mistakenly signals to students that the factual recall of small detail is as important as broader understanding of concepts, ability to relate concepts to one another, and ability to apply those to given problems and scenarios. Clearly, this is a questionable assessment practice [2].

Thus although reliability of MCQ questions in the past papers examined is high, very little in-depth judgement relating to student learning could be made. It was possible to judge the degree to which students were able to recall facts (i.e. student memory was being tested), but too few MCQ questions could provide examiners the opportunity to ascertain depth of understanding of concepts or facts, or the degree to which students might be able to apply or structure their knowledge. Furthermore, the MCQ questions used provided no way of discriminating “top” from “bottom” students, except in terms of effort or ability to memorise.

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1 The South African Computer Lecturers Association (http://www.sacla.org.za)

2 Identical questions that were repeated across exams were counted only once.
Table 1: Classification of MCQ Questions

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</thead>
<tbody>
<tr>
<td>Factual knowledge</td>
<td>171</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conceptual knowledge</td>
<td>16</td>
<td>19</td>
<td>5</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedural knowledge</td>
<td>1</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metacognitive knowledge</td>
<td></td>
<td></td>
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</tbody>
</table>

Figure 1: Percentage of MCQs addressing different levels of cognitive skills

4.3 Phase 2 - Data Collection

To answer the second and third research questions, a preliminary study was undertaken on the use of MCQ questions to test application, analysis and even evaluation of conceptual and procedural knowledge. The study was carried out in the authors’ own institution and was targeted at students in a foundation information systems course. Students in two tutorial groups (n1 = 62, n2 = 57) participated in the study. The prescribed course text is: Stair and Reynolds. (2008). Fundamentals of Information Systems, 4th Edition. Course Technology.

Students were given the opportunity to access and complete (via WebCT) a set of twenty multiple choice questions on the topic of Internet and WWW. No time-limit for completion was set, students could complete the questions in their own time, and students were allowed access to textbooks and class notes.

The Internet and WWW was a topic area where relatively few of the past examination papers reviewed in phase 1 assessed students beyond the level of knowledge recall. Thus it was an appropriate topic in which to explore the possibility of designing MCQs that assess students at deeper levels of cognitive ability (Research Question 2) as well as to determine whether the MCQ questions would appropriately discriminate between top and bottom performing students (Research Question 3).

The Internet and WWW topic was lectured over 4 hours and focused on the history of the Internet; how the Internet works; different Internet services including WWW; and different uses of the WWW. It is considered important to cover these topics in a foundation course to enable students to appreciate and understand the implications of the Internet and WWW for individuals and society, their application for business, and issues surrounding their use. The topic thus serves to demystify the Internet and provide students the foundation knowledge needed for future topics and courses such as E-commerce, web programming, and network management. Typical misconceptions of students in this topic area include the relationship between the Internet and WWW, and the relationship between IP addresses and URLs. Weaker

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1 It is worth noting that these were from a second-year level course that was included in the pool of examination papers. This was due to the role it played as an introductory / foundation IS course.
students also tend to struggle to link all the pieces of the Internet puzzle – it is an area in which even computer literate students will encounter unfamiliar terminology (technical jargon) such as routers, packets, TCP/IP, and client/server architecture.

Prior to setting the questions, a workshop was carried out with lecturers on the use of MCQ questions and the setting of higher order MCQ questions based on the experiences of other disciplines such as education and psychology. The questions were set in order to draw out misconceptions as well as test for student understanding of the big picture as opposed to simply testing knowledge of isolated facts.

Given the open-book nature of the exercise, it was expected that students would do very well in the questions requiring knowledge recall. However, it was expected that only those students who adequately understood concepts, would be perform well in questions testing comprehension, and furthermore comprehension would be a necessary pre-requisite for performance on questions requiring application and analysis.

4.4 Phase 2 - Data Analysis

Figure 2 shows that on average the class scores very well on recall questions. The recall questions have an average difficulty value\(^1\) of 0.85 i.e. most students are able to correctly answer these questions. Students still perform less well on comprehension questions (average difficulty value = 0.64). However, only 60% of students were able to answer the application question correctly, and less than 30% of students were able to answer the analysis questions correctly. Student performance on the questions thus moved in the expected direction. See Appendix for sample of questions.

A common criticism against MCQ questions is that they are not a useful form of assessment for distinguishing between top and bottom students – since success is achieved via simple rote learning and requires little more than a surface approach to learning [12, 13]. This may certainly be the case when the use of MCQ questions is restricted to testing of knowledge recall. However, this study sought to examine whether MCQ questions, specifically designed to test higher level cognitive skills, were capable of distinguishing between top and bottom performers (Research Question 3).

Following the approach of Lister [9], students were separated into quartiles based on their overall scores for the entire set of questions. Figure 3 shows that when knowledge-recall MCQ questions are used, there is little difference in the performance of top 25% and bottom 25% of students. However, for higher level questions (questions 10 through 20) that are focused on comprehension, application and analysis, the variation in performance is much greater. For example, question 10, a comprehension question, enabled strong students to demonstrate their understanding with 73% of top performers answering correctly, while only 24% of bottom performers managed this question. As another example, 87% of the top performers were able to answer the application question (question 18) while only 27% of the bottom performers were able to answer this question correctly. Furthermore, almost no bottom performing students were able to answer the analysis questions (19 and 20) correctly. These results suggest that ‘higher level’ MCQ questions are adequate in distinguishing between top and bottom students.

Although statistically biased because the total test score includes item scores, the above graph together with an analysis of item discrimination scores (point biserial correlations\(^2\)) provide for a similar conclusion about the ability of recall versus higher level questions for discriminating between strong and weak students. Recall level MCQ question have extremely low discriminate scores (less than 0.30 and many are close to zero). This indicates that MCQ questions that focus only on recall are not adequate for discriminating between high and low performers (both strong and weak students perform identically in these types of questions). In a closed book examination, it is expected that the discrimination scores for recall level MCQ questions would be higher, and by implication misleading, because these questions discriminate only by student ability to memorize facts.

Overall reliability of the question set is given by an alpha of 0.619. This falls above the generally accepted reliability of 0.60.

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\(^1\) Difficulty value is a sample specific score that simply identified the percentage of students that answer an item correctly. The range is 0 to 100%. http://www.utexas.edu/academic/mec/research/pdf/writingmcexams_handout.pdf

\(^2\) http://www.eddata.com/resources/publications/EDS_Point_Biserial.pdf
Some specific questions and responses are discussed next (see Appendix for question detail). They illustrate the manner in which MCQ questions can be used to assess each of the levels of cognitive demand (Research Question 2). Problems encountered are also described.

Question 2 was an example of a recall question (difficulty value = 0.87). The question required students to simply refer to and recall lecture slides and textbook content. This level of question is most frequently used in MCQ assessment, and these questions were generally not good discriminators between top and bottom students (Figure 3).

Question 10 was a comprehension question. Students are required to reflect on an unseen scenario and make a recommendation as to the appropriate Internet service. While top performing students answered correctly by identifying (b) as the correct answer, Many students were unable to understand the difference between the concept of an Internet service and the concept of a network protocol (d) – the answer given by a third of the class. This item had a good point biserial correlation (discrimination score) of 0.335.

Question 11 was originally intended as a comprehension question. However, it was answered relatively well (difficult value of 0.87 closely matching recall questions). While the intent of the questions was good, post-hoc analysis reveals that the correct answer closely resembles the textbook description of a search engine. This explains the relatively high performance on the question in both top and bottom performers.

Question 17 was an assertion-reason question that requires students to determine the correctness of each statement, and then to make a judgement as to whether the reason is an acceptable explanation for the assertion. This question had a very low difficulty value of 0.26 relative to the other comprehension questions (i.e. most students got it wrong), and analysis of this item shows a point biserial correlation of 0.269, which suggests a possible problem with the items. Upon reflection, the question may have been worded in a manner that made it slightly ambiguous as to whether the focus of the assertion is the need to use a URL in order to locate a web page, or the need to use a web browser in order to view a web page. This illustrates the importance of wording questions correctly. 42% of students selected option (a) possibly due to misinterpretation.

Question 18 was intended as an application question and 40% of students were unable to correctly answer this level of question. This question required students to demonstrate their understanding of various technologies and apply that understanding to the scenario presented. Given all the options and the reasons presented, the most likely course of action for Sally and Amy should be (d). This required that students are able to dismiss the other options as incorrect, or irrelevant for this particular scenario, or to dismiss the justification for selecting the option (i.e. they could use instant messaging but that would not require Sally to find another way to connect to the Internet i.e. the student needed to understand that Wi-Max does provide a user connection to the Internet). They also needed to draw on their understanding of email as a send-store-retrieve based form of communication that is not real-time, that VoIP is real-time, and they needed to understand that a podcast allows for playback not conversation. This question required both knowledge and understanding before the student could attempt to apply that knowledge to make a recommendation.

Question 19 had a difficulty value of 0.29 but only the strongest of students were able to answer this correctly. The relative even distribution across good, mediocre and unacceptable shows that students were potentially guessing. The correct answer here was (d) because: 1) all uses of the Web are missing (the answer does not identify any uses of the web such as online shopping, banking, social networking, news, education, health, entertainment etc.), 2) the student has confused uses of the Web and Internet services, and has demonstrated a common misconception, 3) although it is a correct statement that the Internet is a physical infrastructure that enables a number of services and that without the Internet the World Wide Web could not exist, none of that is relevant to the question posed to the student. It is all background. Interestingly this type of question highlights student thinking about the manner in which open-ended questions can be answered – “dump down everything you can recall about the Internet and hope something fits” (32% of students felt the answer was “good” clearly illustrating their lack of understanding of the difference between Internet services and uses of the Web. This question illustrates how MCQs can be used to test common misconceptions.

Question 20 had a difficulty value of 0.26, with only the strongest of students able to answer correctly. This question required students to do four things: 1) draw on a number of topics and explanations presented in class around the technologies of the Internet and how the Internet works, A student would need to put a number of puzzle pieces together. 2) evaluate and pass judgement on the fictitious student’s answer, which requires determining both correct and incorrect statements. 3) evaluate each of the possible corrections to determine if they are appropriate. 4) accept that it may not be possible to completely reconcile the answer i.e. inaccuracies may still remain as some suggested corrections may not improve / correct the student’s answer. The majority of students selected (d), which is a partially correct answer. These students were not able to fully evaluate the “correctness” of the recommended correction. The term “peer-to-peer” should have been replaced with “client-server” not “server dominated”. The term “server dominated” was invented and does not appear anywhere in the students course notes, or textbook (even a search on Google for the term “server dominated model” returns no results).

5. ANSWERS TO RESEARCH QUESTIONS

The results of phase 1 clearly show that information systems academics are not currently using MCQ questions to assess students at the higher levels of cognitive demand, specifically, in the context of this study, at the levels of application and analysis. Instead, a review of the examination papers reveals that examiners are relying on short-answer, or paragraph style questions, believing those to be more suited to assessing higher level skills. However, analysis reveals that the majority of those questions also sit at the knowledge recall level and few require students to demonstrate understanding or apply concepts learned. This is evident, by the questions requiring students to list, define, identify, discuss, and describe as opposed to explain, distinguish between, predict the outcome, evaluate, judge, and recommend. The conclusion of the above analysis was that in undergraduate information systems education, MCQ questions are being used to assess lower level cognitive ability and are not being considered for their potential to assess higher level cognitive skills.

The second phase of the study shows that with careful attention to question design, MCQs can be used to tease out common misconceptions, assess higher level cognitive skills, and discriminate between top and bottom students. Moreover,
the use of MCQ questions allows for automated testing and immediate feedback to students on their performance. Mark weighting of questions also needs to be considered so as to ensure that students are given enough time for questions that challenge them at higher cognitive levels.

6. CONCLUSION

The reality of large classes requires a strategic response that balances the tensions between reliability, validity and manageability of assessment methods. Structured MCQ questions can be used to address reliability, validity and manageability. However, the construction of MCQs that assess higher level cognitive skills is not an easy task (not as quick as drawing on the textbook ‘test bank’) and will require investment in time. However, results of this study show that MCQ questions can discriminate effectively between top and bottom performers. Future extensions of this study aim to compare performance in MCQ questions against performance in other components of the course including laboratory work, practical project and written assignments. The authors will also evaluate results in the context of a timed, closed-book examination where a range of topic are covered and where students may fall down on factual recall but still perform adequately on questions of conceptual understanding and application. We also intend to compare results of students intending to major in IS versus non-majors.

REFERENCES


7. APPENDIX: SAMPLE OF MCQ QUESTIONS

<table>
<thead>
<tr>
<th>Question 2</th>
<th>The Internet is a/an</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>circuit switching network</td>
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<tr>
<td></td>
<td>fibre relay network</td>
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<tr>
<td></td>
<td>packet switching network</td>
</tr>
<tr>
<td></td>
<td>optical relay network</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 10</th>
<th>A branch office of a retail chain needs to upload sales data to the head office. Which one of the following Internet services could be relied upon?</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>URL</td>
</tr>
<tr>
<td></td>
<td>FTP</td>
</tr>
<tr>
<td></td>
<td>Telnet</td>
</tr>
<tr>
<td></td>
<td>TCP/IP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 11</th>
<th>Search engines are important for Web research because</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>They allow a revenue system to be generated from advertising, and this revenue allows the Web to be sustainable</td>
</tr>
<tr>
<td></td>
<td>They add value by having sponsored links delivered with the research results</td>
</tr>
<tr>
<td></td>
<td>Users can find the information that they require by searching databases created by the search engines</td>
</tr>
<tr>
<td></td>
<td>Users can search the Web as soon as a new page is created or a website is updated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 17</th>
<th>Assertion: Sally wanted to view a hypermedia document (web page) on the World Wide Web, so she needed to type the URL into the address bar of her web browser</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BECAUSE</td>
</tr>
<tr>
<td></td>
<td>A web browser is client-side software used to access web pages. The assertion and the reason are both correct, and the reason is valid.</td>
</tr>
</tbody>
</table>
The assertion and the reason are both correct, but the reason is invalid.
The assertion is correct but the reason is incorrect.
The assertion is incorrect but the reason is correct.
Both the assertion and the reason are incorrect.

Question 18
Sally (a travelling salesperson currently in Durban) and Amy (her boss at head office in Johannesburg) want to have a conversation about the sales calls that Sally made that day. Sally has an Internet connection via Wi-Max. Which of the following is the most appropriate choice in the circumstances?

They should use email because it allows for real-time communication
They should use instant messaging only if Sally can find another way to connect to the Internet
They should use VoIP even though it will not allow for real-time communication
They should use video-conferencing because it supports both voice and visual communication
They should use a podcast because it will allow Amy to ask Sally questions

Question 19
A student was asked the following question: “Briefly list and explain the various uses of the Web”. As an answer, this student wrote the following:
“The Internet is a physical infrastructure that enables a number of services. Without the Internet, the World Wide Web could not exist. Various uses of the Web include: email, FTP, IRC and VoIP. Email accounts for the majority of Internet traffic.”
How would you judge this student’s answer?

EXCELLENT (all uses of the Web have been identified with clear and correct explanations)
GOOD (all uses of the Web have been identified, but the explanations are not as clear as they should be).
MEDIocre (one or two uses of the Web are missing, or the explanations are not clear OR the explanations are irrelevant)
UNACCEPTABLE (more than two uses of the Web are missing AND the explanations are not clear AND/OR they are irrelevant)

Question 20
A student was asked the following question: "Briefly list and explain the technologies that make the Internet work". As an answer, this student wrote the following:
“The Internet is a physical infrastructure that enables a number of services. Firstly, it is important to recognize that the Internet is a circuit-switching network. This allows for messages to be broken up into packets and dynamically routed to the destination computer. TCP/IP is the communications protocol for the Internet. The protocol defines how messages are broken up into packets, addressed, delivered and reassembled. Routers are computers on the Internet responsible for the forwarding of packets. All computers on the Internet require a unique TCP address. Most Internet services rely on a peer-to-peer computing model. For example, the Web is based on a peer-to-peer model.”
You are reviewing the work in an attempt to help detect the errors and fix the answer. Which of the options 1 - 5 represent good corrections to make?

1. The word “circuit” should be replaced by “packet”
2. The word “Routers” should be replaced by “Domain name servers”
3. The term “TCP address” should be replaced with “IP address”
4. The term “peer-to-peer” should be replaced by “server dominated”
5. The word “Internet” should be replaced with “World Wide Web”

1 to 5 are all correct
1, 2, 3 and 4 are correct but 5 is incorrect
1, 2 and 3 are correct but 4 and 5 are incorrect
1, 3 and 4 are correct but 2 and 5 are incorrect
1 and 2 are correct but 3, 4 and 5 are incorrect
1 and 3 are correct but 2, 4 and 5 are incorrect
Searching for the Technology in Universities of Technology

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School of Computing, UNISA, South Africa
Meraka Institute, CSIR, South Africa

ABSTRACT

Higher education in South Africa has been the scene for dramatic changes during the last fourteen years of the new democracy. The cleanly divided domains and roles of higher education institutions made way for a chaotic situation that was eventually resolved by the creation of three different kinds of universities. Universities of technology as previously vocational training institutions gained academic legitimacy with the title of university and the right to deliver postgraduate outputs. The problem that arises out of this new order is the claim that technology defines the uniqueness of a university of technology. The public image of the five universities of technology in South Africa is analysed in order to validate this claim.

CATEGORIES AND SUBJECT DESCRIPTORS

K.m [Miscellaneous]

GENERAL TERMS

Management, Economics, Human Factors.

KEYWORDS

Technology in university of technology; technological knowledge; higher education; philosophy of technology education framework; higher education framework.

1. INTRODUCTION

The backdrop of any discussion of education in the South African context is the political changes that started after the first truly democratic election in 1994 and that still continue to this day. With the changes in political order in South Africa came the will to change the social order of the country and its people, an agenda aptly described by the slogan: “a better life for all” 4. Significant historical events such as the Soweto uprising [35] made education an important aspect of the struggle for freedom in a country marked by the segregation and discrimination of whole groups of people and lead to sweeping reforms to unite the country’s disparate and fragmented educational environment. This process started in the early 90’s as an initiative of the National Union of Metalworkers in conjunction with the Congress of South African Trade Unions (COSATU) [1], and is still not completed. The deliberate efforts in the new democracy to redress the inequalities of the past are visible in many sectors of the country, including the higher education landscape. A particular and very visible example of this can be seen in the changed structures of higher education institutions which in the previous dispensation were delineated as universities and technikons. These institutions now find themselves labeled as traditional universities (TU), comprehensive universities (CU) and universities of technology (UOT) [15]. The latter of these creations, universities of technology, enjoy substantial attention by way of debate and is the focus of this paper.

Du Pre [9] argues that technology is the qualifying factor for a UOT and adds that its purpose is to “make knowledge useful”. Winberg [40] in turn calls for an “epistemology of technology”. This call is, however, not easy to answer. One reason for this difficulty is the possibility that philosophy is not seen as technology [36] and another reason is the lack of clarity on the meaning of the term technology. This leads to an inherent identity crisis, which is apparently resolved by the claim that UOTs are different from traditional universities. The problem with this solution is that UOTs may know internally what that difference is, but it is not apparent in their public image.

In the international context technology is viewed as a critical component of national education development. This is

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2 Paula.Kotze@gmail.com,
3 vdmeraj@unisa.ac.za
4 The slogan "A Better Life for All" has been the call of the African National Congress in its election campaigns since 1994
evidenced in the number of countries that have examined, and established, the role of technology in national education. Examples of these are the New Zealand Education Department [24] and the Technology for all Americans project [17].

The technology focus of the South African government is readily seen in the outcomes of the curriculums of the lower bands of the South African National Qualification Framework (SANQF). Its role and place in the qualification programs of higher education is, however, not as clear, even when considering the occurrence of professional engineering degrees and information and communication technology (ICT) courses.

The purpose of this paper is to explore the place and meaning of technology in the South African UOT context. The debate over the existence of a UOT came to an end with its creation as a new kind of higher education institution. This significant step was to the benefit of technikons because it provided the much sought after academic legitimacy that comes with the designation of university. What is left unclear though is the meaning of the term technology in this context. A new chapter in the debate is therefore needed with the goal to examine and contextualize technology in the operative domain of UOTs. This will in part follow on Du Pre’s [9] work as well as set the scene for answering Winberg’s [40] call for an epistemology of technology.

The remainder of this paper is structured in two parts. The first part is a broad overview of the aspects of technology as it relates to education on a national and international level. The scope for this part is very wide and an in-depth analysis is not possible. The aim is therefore to show that the topic of technology in education, both on the level of child education as well as higher education, has, and still is, enjoying tremendous attention. Furthermore a brief historic overview of education in South Africa will provide the needed context for the rest of the paper.

The second part is more specific and focused in that it examines the public image of UOTs. The aim is to discover how UOTs market itself to the “outside world” and is therefore used as an indicator of identity. The point is that school leavers, who have already been exposed to an organized and rationally designed curriculum on technology, will be seeking to further their education in technology. UOTs seem to be the ideal place of study for these students. These institutions are, however, new to the scene in terms of identity and still fall back to the vocationally focussed products of their previous state of existence, namely technikons. The question that is raised is whether UOTs in relation to technology brings new understanding or whether it is the same thing with a new name.

The paper concludes with comments that will serve as the opening remarks for a debate on the role and meaning of technology in the context of UOTs. This will in time result in a broader debate on the role of technology in all of South Africa’s different higher education institutions.

What is Technology and Technological Knowledge?

Mitcham [23] describes technology as the making and using of artefacts by humans. The glossary of the International Technology Education Association’s (ITEA) Technology for All Americans Project (TIAAP) describes technology as: “the innovation, change, or modification of the natural environment to satisfy perceived human needs and wants” [16]. The New Zealand Ministry of Education [25] in turn describes technology as: “a creative, purposeful activity aimed at meeting needs and opportunities through the development of products, systems, or environments”. Knowledge, skills, and resources are identified as key to help solve practical problems. This and other attempts at definitions and descriptions of technology (see for example Hansen and Froelich [14]) emphasizes the making of artefacts and the role of humans in this process. To settle this definition will steer the paper in a philosophical direction and will inhibit its purpose. In order to promote the debate the definition of technology is taken from as wide a perspective as possible providing that the emphasis on human making for human needs is strongly maintained.

Knowledge forms an integral part of the discussion on technology and its place in education. The Committee on Technological Literacy lists the dimensions of technological literacy as knowledge, ways of thinking and acting, and capabilities [26]. The link between technology and knowledge is not a new concept [20]. McCormick [22] describes procedural and conceptual knowledge as part of this technological knowledge. Table 1 shows the technological knowledge framework developed by Compton [5] for the New Zealand Ministry of Education.

The framework shows the extremes of the spectrum of knowledge in technology. The value of this framework in the current discussion is in the context it provides for thinking of technology and knowledge in education. An institution such as a UOT can, for example, orient itself in this structure with regards to the level of academic discourse it wants to participate in. On the other hand this framework is useful to guide the wider debate on the general place of technological knowledge in the activities of higher education.

Table 1: Technological Knowledge Framework [5]

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
<th>Links</th>
<th>Knowledge Type(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social knowledge</td>
<td>Understanding of the social and physical environment of any technological development or site into which a technology is to be embedded. It includes knowledge of appropriate ethics, legal requirements, cultural or domain protocols and the personal/collective needs of the end-users and technologists</td>
<td>Ropohl’s Socio-Technological Understandings [30]</td>
<td>Explicit and tacit descriptive conceptual, prescriptive device and evaluative procedural</td>
</tr>
<tr>
<td>Resource knowledge</td>
<td>Understanding of the use and management of resources in any technological development or ongoing maintenance. The physical properties of resources and their current and long-term availability would come under this category</td>
<td>De Vries’ Physical Nature Knowledge [8] and Technological laws [30] and the operationalisation of Theoretical tools and Quantitative Data [39]</td>
<td>Explicit prescriptive device and descriptive conceptual</td>
</tr>
</tbody>
</table>
2. THE CONTEXT: THE SOUTH AFRICAN EDUCATION STRUCTURE

The South African Department of Education (DoE) is mandated by the government to oversee all matters pertaining to education. In this capacity, it formulates policies, creates laws and executes the government’s desire for an education system that exists to serve all of the citizens of this country equally. Towards this goal, the SANQF was designed to facilitate the coordination of lifelong learning amongst a variety of public and private institutions of learning [31]. The SANQF, under the auspices of the South African Qualifications Authority (SAQA), is subdivided into three bands: general education and training (GET), further education and training (FET) and higher education and training (HET). The following four subsections give a succinct overview of the SANQF and briefly identify the role of technology education within this landscape.

2.1 The South African National Qualifications Framework

The responsibility of SAQA is to oversee the development and implementation of the SANQF [31]. Figure 1 shows the structure of SAQA. In the task of standards setting and quality assurance Education and Training Quality Assurance bodies (ETQAs) are created to represent the interests of professional stakeholders. In the case of higher education the Higher Education Quality Committee (HEQC) fulfils this role. The purpose of the framework is to “improve the coherence of the education system” as well as “facilitate the articulation of qualifications” [33]. An overview of the structure of the SANQF can be seen in Table 2.

<table>
<thead>
<tr>
<th>Band</th>
<th>NQF Level</th>
<th>Qualification Type</th>
<th>Sublevels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Education and Training (HET)</td>
<td>Postgraduate</td>
<td>Bachelor’s Degree</td>
<td>10 Doctoral Degree</td>
</tr>
<tr>
<td></td>
<td>Undergraduate</td>
<td>Degree</td>
<td>9 Master’s Degree</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Honours Degree</td>
<td>8 Bachelor Degree</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Postgraduate Diploma</td>
<td>7 Bachelors Degree</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advanced diploma</td>
<td>6 Advanced Certificate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diploma</td>
<td>5 Higher Certificate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 Further School / College /</td>
</tr>
</tbody>
</table>

Table 2: SANQF
The adoption of the outcomes based education (OBE) emerges from the pre-university education bands. In the GET band technology enters the scene as a clear is that at least two kinds of educational streams are included namely theoretically oriented (labelled as degrees in HET) and vocational (labelled as diplomas in HET). This is expressed in the issue of articulation between these two streams. Whether an institution aims its education programs at being primarily vocational or primarily theoretical is not critical, what is important is the ability for learners to cross this divide. The next sections will show how the curriculum descriptions of the pre-university education bands have positioned technology, as well as the absence of such an initiative by UOT’s.

### 2.2 Pre-university Education

The adoption of the outcomes based education (OBE) philosophy has revolutionized school education in South Africa [7]. After ten years of work a measure of stability is being achieved with the outcomes for each learning programme established and the first groups of learners to emerge from the pre-university education bands.

Technology is a well defined part of the content of these bands. In the GET band technology enters the scene as a learning programme, that is integrated in the learning programmes of each grade [32]. On the FET band technology is refined into six separate learning programmes [34]. These are agricultural technology (focusing on technological processes used in agriculture and the farming environment), civil technology (focusing on concepts and principles in the built environment and on the technological process), computer applications technology (focusing on the effective use of information and communication technologies in an end-user computer applications environment in different sectors of society), electrical technology (focusing on the understanding and application of electrical and electronic principles), information technology (focusing on activities that deal with the solution of problems through logical thinking, information management and communication, and on the development of computer applications using current development tools), and mechanical technology (focusing on technological processes from conceptual design through the process of practical problem solving for the improvement of the different mechanically related processes, services, systems and the control thereof used in the production and manufacturing of goods). These subjects are available for selection from Grade 10 to 12 of the learner’s studies.

Although an in depth discussion of these subjects fall outside the scope of this paper, it is important to emphasize the fact that in preparation of a learner for higher education (or for the labour market) technology enjoys substantial attention. This of course directly affects universities, and specifically UOTs, since it is these students that will be looking for a continuation of a technologically-oriented study career.

### 2.3 University Education

As noted earlier, higher education in South Africa has undergone tremendous change during the past few years. The DoE is responsible for executing the government’s vision for a system that is fair and open in terms of educating the citizens of the country. In that capacity it created the three types of universities, namely TUs, CUs and UOTs [15]. Kraak [19] ascribes the creation of UOTs to political pressure more than a “planned policy evolution from the state”.

The most significant result of the redesign of higher education is the creation of the UOT. The roots of this new type of institution are found in a strong historical relationship between education and technology [21]. Winberg [41] describes three phases of the development of UOT’s as: educating for the needs of industry, imitating universities and rediscoversing technology. The argument is clearly toward a growth from a vocational-oriented education towards that of critical thinkers [41].

The traditional and original intention of technikons was to equip students with hands-on skills for the workplace. This emphasis gave technikons the reputation of being practical as opposed to the strictly theoretical purpose of universities. In addition to this, the entry requirements between universities and technikons were different: a school leaver needed a university exemption to prove a certain level of academic aptitude to be admitted to a university, whilst technikons had lower entry level requirements.

### 2.4 International Trends

South African researchers are not alone in the quest for an understanding of technology and its place in education. On the international front a significant body of work is being done by researchers on the question of technology education. These initiatives is as far reaching as that of small former British colonies [29], European countries [27] and finally large developed countries such as the United States of America [18]. The efforts of these researchers have bearing on the search for the meaning of technology in the educational context. A comprehensive overview is beyond the scope of this paper, but certain issues, such as a definition of technology and the place of knowledge in technology, is of relevance (see above).

### 3. WHERE IS TECHNOLOGY IN THE SOUTH AFRICAN CONCEPTION OF A UOT?

Philosophers have contributed greatly to an understanding of the conceptual dimensions of technology and researchers from an array of disciplines added to the debate on technological
knowledge. All of these results are critical in the discovery of what the South African conception of a UOT is.

In order to formulate a South African understanding of the notion of a UOT it is necessary to look beyond the philosophical discussions and intellectual creations of the academics. The fact that these institutions have already been established, and have been in existence for more than 2 years, gives an opportunity to examine what they themselves are saying with regards to themselves. This section asks questions on where technology can be found in the South African UOT.

To facilitate this question, an analysis of the different vision and mission statements of each UOT was conducted and is discussed in the following sections. In addition to this the faculty structure was also examined to get a public view of what these institutions say about themselves.

3.1 Can Technology be Found in the Public Statements of UOTs?

Collins and Porras [4] describes an organization as consisting of the two components of a guiding philosophy and vivid picture. The guiding philosophy is described as “a system of fundamental motivating assumptions, principles, values and tenets”. It is also said to come from the early leaders who originally shape the organization. The tangible image on the other hand consists of a mission and a vivid description. The purpose of the tangible image is to “focus people’s attention on a certain goal” and is described as “bold, exciting and emotionally charged”.

This framework makes it possible to provide guidance to the leaders of UOTs in the creation of a guiding philosophy for their institutions. Fortunately the seminal work of Du Pre [9] has set out a philosophical perspective targeted at the creation of UOTs in South Africa and is fit for the purpose of a starting point of the effort as a whole. At the same time the top management of UOTs are faced with “selling” this new idea to prospective students.

This section reports on an analysis of the vision and mission statements of the five South African UOTs. The analysis took into consideration that the newness of the UOT idea and the reality of mergers place all these institutions in the beginning phases of a corporate lifecycle. The specific life cycle phase of UOTs is hard to determine, but considering that these new institutions result from mergers it could be placed on Hanks et al.’s [13] expansion or consolidation phase. The phase prior to this is generally the start-up phase and the phase immediately after this is the maturity phase. The analysis made use of the Collins and Porras [4] framework to identify first the guiding philosophy and second to see the tangible image of each UOT. The purpose of this analysis is to determine the vividness and inspirational role of UOTs as they appear to public scrutiny, as well as to find the place of technology in this image. The data for the analysis was gathered directly from the institutional websites.

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### 3.1.1 Guiding Philosophy

The guiding philosophy is measured against the aspects of core values and purpose (see Table 3). The critical metrics here is the clarity of the values as it relates to the role of technology and the way in which the purpose is an expression of this belief.

### Table 3: Core values and purpose

<table>
<thead>
<tr>
<th>UOT</th>
<th>Core Values</th>
<th>Purpose / Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cape Peninsula University of Technology (CPUT)</td>
<td>Integrity, respect, excellence, democracy, accountability, ubuntu, innovation, equity</td>
<td>To be at the heart of technology education and innovation in Africa [2].</td>
</tr>
<tr>
<td>Central University of Technology (CUT)</td>
<td>Customer service, integrity, diversity, innovation, excellence</td>
<td>To be a globally connected African UOT that focuses on the needs of Southern Africa and supports graduates for citizenship with skills and competencies in appropriate technologies [3].</td>
</tr>
<tr>
<td>Durban University of Technology (DUT)</td>
<td>Not directly observable</td>
<td>A leading UOT in Africa that nurtures holistic education and the advancement of knowledge [11].</td>
</tr>
<tr>
<td>Tshwane University of Technology (TUT)</td>
<td>Quality service, professionalism, integrity, excellence, equity, unity in diversity</td>
<td>To be the leading higher education institution in Southern Africa with an entrepreneurial ethos that promotes knowledge and technology; and provides professional career education of an international standard, which is relevant to the needs and aspirations of Southern Africa's people [37].</td>
</tr>
<tr>
<td>Vaal University of Technology (VUT)</td>
<td>Not directly observable</td>
<td>To be a dynamic centre of technology leading in quality education for the nation [38].</td>
</tr>
</tbody>
</table>

The core values presented in Table 3 shows no specific reference to the role of technology in the core values of any of the institutions. CPUT for example mentions democracy whilst TUT indicates professionalism. Each institution states a belief that they exist to play a valuable role for the market it serves, in line with the education goals and needs set out by the DoE. The specific role of technology comes into focus when the purpose statements are considered. Technology is presented as either an environment of study (VUT), or something to impart (TUT, CUT) or a particular kind of education (CUT). These institutions view themselves as rooted in the country needs and in different ways present a solution dependant on what technology offers. This view is in line with the Collins and Porras [4] framework and together with the designation of UOT presents a unity of thought.

### 3.1.2 Tangible Image

The tangible image is the mission of the organization so that its efforts are clearly focused. If the guiding philosophy presented an abstract view on the “what” aspect on the organization then the tangible image presents the “how” and
therefore the practical realization of the vision. The critical metric in this analysis is the ability of the tangible image to inspire those that read it. The mission was examined for its ability to clearly express how the vision will be achieved and again the role of technology is sought out. Furthermore, the motto was examined for emotive language as an indicator of the desire from the UOT to inspire people. The mission and motto is for the five institutions are presented in Table 4.

### Table 4: Mission and motto

<table>
<thead>
<tr>
<th>UOT</th>
<th>Mission</th>
<th>Motto</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPUT</td>
<td>To develop and sustain an empowering environment where, through teaching, learning, research and scholarship our students and staff, in partnership with the community and industry, are able to create and apply knowledge that contributes to development</td>
<td>Not directly observable</td>
</tr>
<tr>
<td>CUT</td>
<td>To deliver high-quality appropriate science, engineering and technology academic programmes supported by applied research; engage with the community for mutually beneficial development; attract and retains expert staff and supports their development and wellbeing, and forge strategic partnerships</td>
<td>Thinking beyond</td>
</tr>
<tr>
<td>DUT</td>
<td>To serve the needs of developing societies within a dynamic global context and to enable quality teaching, learning, research and community engagement by providing quality, career-focused education, and promoting a values-driven ethos, sustainable partnerships with industry, community and society, excellence in applied and relevant research and; empowering staff and students to succeed and ensuring institutional sustainability.</td>
<td>Not directly observable</td>
</tr>
<tr>
<td>TUT</td>
<td>To create, apply and transfer knowledge and technology of an international standard through cooperative professional career education programmes at undergraduate and postgraduate levels; serve and empower society by meeting the socio-economic development needs of Southern Africa through the fruits of our teaching and the skills of our staff and students; extend the parameters of technological innovation by making knowledge useful through focused applied research and development; and establish and maintain a strategic partnership network locally and internationally for the mutual benefit of the institution and its partners.</td>
<td>We empower people</td>
</tr>
<tr>
<td>VUT</td>
<td>To achieve excellence in teaching and learning endeavours by developing entrepreneurial, technological and cognitive skills, to create an environment conducive to develop behavioural, attitudinal competencies and social skills through cultural, sporting and personal development activities; to generate innovative and relevant research which solves the problems of industry and the community; and to create a culture of lifelong learning to empower our communities by sharing knowledge, skills and resources.</td>
<td>Your world to a better future</td>
</tr>
</tbody>
</table>

The three aspects common to the missions are that of a community involvement or relatedness, research and, of course, teaching. The role of technology is not as clear as can be expected of a UOT. One of the roles of technology is encapsulated as the content of what is taught (TUT), but more generally it takes the form of the purpose and aim of applied research (CUT). Apart from this the mission statements do not explicitly identify a university as a UOT. A motto was found at three of the five institutions and the emotive quality only really applies to that of TUT and VUT.

As an image to the public none of the elements addressed creates a particular view of what a UOT is or does. One possibility reason for this is that these institutions rely on their names to create enough of a drawing card for interested students. In addition to this is the nature of the naming of qualifications (for example BTech: Computer Systems) presented at these universities. This uniqueness in itself provides a level of identification for prospective students.

### 3.2 Can Technology be found in the Faculty Structures of UOTs?

This section looks at the faculty and departmental structures as described by the institutions under examination.

During data collection each UOT’s homepage was visited to capture information on the naming of its faculties and departments. The reason for this was the clarification it brings with regards to how the different UOTs differentiate
themselves by way of structure. In addition to this, the name of the faculty or department provides a partial internal view of technology held by the UOT.

Table 5: Faculty names

<table>
<thead>
<tr>
<th>UOT</th>
<th>Faculty Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPUT</td>
<td>Applied Sciences, Business, Education and Social Sciences, Engineering, Health and Wellness</td>
</tr>
<tr>
<td></td>
<td>Sciences, Informatics and Design</td>
</tr>
<tr>
<td>CUT</td>
<td>Engineering, Information and Communication Technology, Health and Environmental Sciences,</td>
</tr>
<tr>
<td></td>
<td>Management Sciences</td>
</tr>
<tr>
<td>DUT</td>
<td>Accounting and Informatics, Applied Sciences, Arts and Design, Engineering and the Built</td>
</tr>
<tr>
<td></td>
<td>Environment, Health Sciences, Management Sciences</td>
</tr>
<tr>
<td>TUT</td>
<td>Economics and Finance, Engineering and the Built Environment, Humanities, Information and</td>
</tr>
<tr>
<td></td>
<td>Communication Technology, Management Sciences, Science, Arts</td>
</tr>
<tr>
<td>VUT</td>
<td>Applied and computer science, Engineering and Technology, Management sciences, Human sciences</td>
</tr>
</tbody>
</table>

Table 5 is a summary of the various faculty names as found on the websites of the UOTs under examination. A significant absence of the term technology as well as an overwhelming use of the term science is noted. Although it would be speculative to explain this phenomenon without deeper analysis, it could be said that, in terms of the naming of a UOT faculties, technology is viewed as the application of science. Technology as a term though is not found, except for its occurrence in ICT.

4. DISCUSSION

The search for technology is in essence the search for the meaning of technology in a certain context. The thought leaders of the idea of a UOT lay claim to the identifying feature that technology brings. The issue then of what the meaning of technology is for UOTs, is a question of critical importance since the operation and strategic direction of a particular kind of higher education institutions affects all others. In part academic drift Kraak [19] describes this situation and suggest that higher education institutions end up being competitors instead of partners in the education goals of South Africa.

The debate on creating a UOT was lively as many commentators spoke in favour as well as against this type of institution (see for example the summary by Reddy [28]). Du Pre [9] stands out as an important thought leader in favour of UOTs and his work can be regarded as seminal in the context of the debate. Du Pre’s work is representative of the tireless efforts of an organization named the Committee of Technikon Principals (CTP) that played a key part in the creation of UOTs. As a statement Du Pre’s work is taken up in various forms in at least two formal publications [9, 10] and most papers participating in the UOT debate cite his work or that of the CTP’s (see for example Thathiah and Schauffer [36] and Imenda [15]). This notable work and the position it has in the domain of UOTs therefore forms an important part of the analysis.

A thorough examination of this seminal work as well as its influence in the formation of UOTs falls outside the scope of this paper. What is presented here is a short overview of the main points made towards its role as a guiding philosophy. The most distinguishing feature of this work is the very inspirational statement of the purpose of UOTs as “making knowledge useful” [9]. This in itself could qualify as the kind of motto that creates a tangible image. Another feature which stands out very clearly is the claim that the distinguishing factor of UOTs is that of technology. Seen in a critical light the proposed definition of a UOT is not fully developed except for the emphasis on the aspects of creating and managing technology. In addition to this, the definition of technology is cast in an applied science guise, thereby excluding any possibility that technology can be distinct and separate from science.

What is clear from the analysis this far is that the role of technology is paramount. The term occurs with enough frequency in the mission and vision of these institutions to support the intention to be an institution that teaches technology. The problems occur when the analysis goes deeper towards the faculty name level where technology is suggested to be applied science. Authors such as Kraak [19] and Reddy [28] states the vocational task of technikons as also that of UOTs. A reasonable connection between vocational education and applied science can be made and the analysis supports this view. UOTs therefore can be said to hold the view that technology is applied science.

5. FRAMEWORK FOR DEBATE

The term university has a generic meaning in the South African context in that it denotes a place of higher learning. The specific identification of the institution comes from secondary labels, such as the distinguishing factors in the design of higher education between a theoretical way of learning and a more practical approach [12]. Imenda’s [15] analysis is instructive as it describes the nature of traditional universities as ideological and that of universities as functional. The lines of the historical debate is thus based on the theory versus practice divide, and can be expressed as in the vocational character of first technikon and now UOT education. The SANQF furthermore supports this delineation with streams of education that focuses on vocational training and theoretical training.

The issue that this paper raises is that in the context of technology as an identifying characteristic, careful thought is needed about the meaning of the term. The call for an epistemology of technology [40] and the philosophical groundwork of Du Pre [9] suggest that the vocational positioning of technical education is too limited for a UOT and need to be broadened. This broadening of the scope of technology education is not found in the public image of UOTs and shows the limit that UOTs inherently place on themselves.

To enable the debate of the role of technology a framework for discourse is needed. Mitcham [23] developed such a framework. Mitcham’s framework (illustrated in Figure 2) consists of thinking about technology in four human and technological interaction modes: object, action, knowledge and volition. He uses these four models to introduce a “provisional” framework and broad definition of technology. The centrality of people to this thinking is seen by the inclusion of human beings as the role players in the making or using of technology, and finally the objects or artefacts represent the output of human effort. Internally humans hold knowledge about technology and also a will to use that knowledge.
7. CONCLUSION AND FUTURE RESEARCH

Technology in this context cannot in any useful sense be owned, but institutions such as UOTs can lead the way towards an integrated understanding of the role of technology and science in the country. There is no doubt that a healthy economy is very dependent on modern technology such as computers, digital networks, and the ability to build cities, genetic engineering, and so on. Humanity possesses great creative power and technology is one expression of this power. Where science aims to understand the world and the principles that define it, technology helps humans to exist in that world.

As was indicated earlier in this paper a broad view was taken with the express purpose to start a debate. One result of this attitude is the absence of a treatment on the role of CUs in this debate. This is an unfortunate side effect of focussing attention on UOTs. The reality of the matter is that CUs represents a combination of both the features of a TU and UOT and could perhaps represent the ultimate vision of where vocational and professional higher education meets. That, however, must and should be the topic of another paper that hopefully will flow from this debate.

An epistemology of technology lies at the core of the debate asked for in this article. This is a philosophical undertaking and must be, in part at least, be attempted by those who would lay claim to the term. The tools described in this paper provide the means to do so. As a final word the end result of this debate is to bring about a significant shift from “making knowledge useful” to “making useful knowledge”.

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Iterative design and evaluation of an e-learning tutorial: a research-based approach

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ABSTRACT
This paper introduces the computer-aided instruction (CAI) tutorial Karnaugh, outlining its design, development and evaluation. Karnaugh is used for supplementary learning in the module Computer Systems: Fundamental Concepts.

E-learning applications require rigorous evaluation of their functionality, learning content and usability. In the case of Karnaugh, this was done in a participative action research approach over two years. Evaluation and reflection occurred in iterative cycles, followed by active responses in the form of revised designs, with the researcher-designer playing a participative role as Karnaugh evolved through five variants. Complementary usability evaluation methods were used, namely heuristic evaluation, end-user questionnaires and interviews. The evaluation criteria were based on an adaptation of Squires & Preece’s ‘learning with software’ heuristics.

The unexpected discovery of some flawed data provided lessons in questionnaire administration.

CATEGORIES AND SUBJECT DESCRIPTORS
H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems – evaluation/methodology;
K.3.1 [Computers and Education]: Computer Uses in Education – computer-assisted instruction (CAI).

KEYWORDS
Design, Human Factors, Measurement.
CAI tutorial, e-learning, evaluation criteria, evaluation methods, learner-centred design, participative action research, usability.

1. INTRODUCTION
The Centre for Software Engineering (CENSE) in Unisa’s School of Computing is re-engineering its interactive computer-aided instruction (CAI) applications that were originally developed in the 1990s. E-learning applications – particularly those in the form of CAI tutorials – are very different from commercial task-based software. Learners, often novices, must be able to use a system before they can even begin to engage with the functions and learning content. Usability of e-learning applications is thus currently an evolving focus area. We have been using a participative action research approach which embodies iterative cycles of active design, evaluation and reflection. From the various usability evaluation methods (UEMs), we selected empirical methods such as heuristic evaluation and surveys via questionnaires and interviews [8, 15]. Evaluation of e-learning should address functionality, usability, interaction design, and learning effectiveness. Ardito et al. [3] state that pedagogic usability, learning tools, content, interfaces, and tasks aimed at the learning outcomes, should all be considered, as well as conformance of the design to traditional usability guidelines. There are specialized requirements for evaluating educational software and web-based learning [16, 17]. Usability evaluation of e-learning is different from that of conventional software, in that functionality and usability are tightly linked [11].

This paper sets out to answer two research questions with the CAI tutorial Karnaugh as target system:
1. How can the design, redesign and evaluation of e-learning be supported by an action research ethos?
2. What kind of findings emanate from the various evaluation methods?

Section 2 sets out the context and content of Karnaugh, while Section 3 outlines the research design. Section 4 introduces the design of Karnaugh and Section 5 presents the findings of the evaluations.

2. BACKGROUND
Some definitions of e-learning associate it only with the use of the Internet and Web. We subscribe to a broader approach that views it as teaching and learning via multiple information technologies, including CD-based software, such as CAI tutorials and multimedia lessons.

2.1 Context of ‘Karnaugh’
UNISA is an open distance-learning (ODL) institution. Most students live in South Africa, but there is an emphasis on outreach to the broader Africa. The learner profile is changing
from part-time students to young, full-time learners, mainly from historically disadvantaged groups, some of whom study at UNISA’s regional learning centres. Communication is by conventional mail, but tutorial matter is also available online. Computing students, by definition, have access to PCs, but not always to the Internet.

The 1st level module, Computer Systems: Fundamental Concepts, (COS113W) addresses the basics of hardware and software, and has some 1000 registered students annually. Two thirds of these students take it to completion and write the examination. The tutorial matter comprises a text book, a study guide and regular tutorial letters that include solutions to assignments. The module teaches the use of Karnaugh diagrams which is a convenient way of representing Boolean functions. The diagrams can be used to simplify Boolean functions by application of a set of rules. They are applied in two thirds of the examination paper.

2.2 Content of the CAI Tutorial ‘Karnaugh’

The interactive multimedia CAI lesson, Karnaugh, was custom-built as optional supplementary study material for COS113W. It has tutorial functionality [2] and offers extensive practice opportunities as it alternates teaching segments with exercises. Instructional transactions involve two-way transfer of knowledge and skills. Karnaugh was designed, evaluated and released as a tutorial on a diskette in 1992 and saw effective use for 13 years, with one revision in 1998. When it was scheduled for re-engineering in 2005, the present module leader led the project. The general approach and subject matter were re-used, but with major extensions. The lesson was made more effective because human-computer interaction (HCI) aspects such as fonts, backgrounds, screen displays, colours, colour-coding, and design of the interaction, were improved. The 2005 version was developed on the multimedia authoring platform, Quest 7.0 as optional study material, and is sold at a reasonable price. It is also available for use, free of charge, in UNISA’s computer laboratories, where many students can access it.

The current version of Karnaugh is structured into sub-lessons: Introduction, Background knowledge, Sum-of-minterms, Karnaugh diagrams and Simplification of Boolean expressions, each with its own subsections. Learners choose which to do, in what sequence, and how many times. Theoretical concepts, processes and examples are presented step-wise, illustrated by graphics, pictures and developing animations. Tutorial units are interspersed with exercise-and-practice and each sub-lesson ends with a summary for revision. Karnaugh diagrams come from a well-structured computational domain where the exercises demand cognitive skills and each exercise has a single correct solution. This is in contrast to ill-structured domains where a variety of acceptable solutions exist [9, 10]. Most questions have a fill-in-the-blank/s format. Feedback and explanations are provided, with options to go back to examples or theory sections. Second attempts must be made after wrong answers.

Karnaugh caters for different stages of learning, offering students the option to omit theory and worked examples and a choice between basic or more complex questions. Karnaugh’s purpose is non-threatening learning support. It does not provide formal assessment or learning management and, although there is an optional capstone test, the score is not recorded.

3. RESEARCH DESIGN: PARTICIPATORY ACTION RESEARCH

An action research (AR) approach [12, 13] was used to design, develop and evaluate Karnaugh. AR can incorporate various research methodologies. It generates action outcomes relevant to the immediate context and research outcomes that inform future work. It is well suited to educational research, where developing artefacts or interventions are studied over a series of cycles. Based on a participative, practitioner-researcher approach, it functions as a change agent as it addresses real-world problems that require action. AR processes [4, 5, 7, 18] are:

- **Cyclic**: Iterative steps – see Figure 1 – occur longitudinally over time.
- **Participative**: Researchers and users collaborate, often with the practitioner-researcher investigating and planning evaluation of his/her own work, hence the central role in the cycles of Figure 1.
- **Qualitative**: Data is often more verbal than numeric, although quantitative methods are also used.
- **Reflective**: Critical reflection on the process and outcomes occurs within each cycle. It is used to plan and design the next actions.
- **Responsive**: AR responds and adapts to findings of previous cycles. Finally the cycle of Figure 1 closes in on a close-to-optimal solution.

The iterative research, responsive development and formative evaluation done on Karnaugh since its inception in 1992 is in line with the generic AR model in Figure 1. The researcher-designer (who is the present module leader) has a central involvement in the series of cycles; each cycle involving action, observation and evaluation. Reflection and responsive actions in the form of improvements lead to the next cycle, where participative inputs by peers and learners are again used to refine the artefact.

![Figure 1. Action research model (diagram synthesized by De Villiers, 2005)](image)

Design and evaluation are not separate, discrete stages in AR. They occur alternately in a tightly-linked, integrated way, continuously informing each other within the cycles. To simplify presentation, however, they are described under separate headers in this paper. The following two sections focus, respectively, on the process and features of design and on the evaluation events and findings.

4. DESIGN OF KARNAUGH

In a participative design approach, the 2005 team comprised the researcher-designer, UNISA peers, programmers, and a graphical designer working in a strong collaborative partnership. The design, developed on the multimedia authoring platform Quest 7.0, has several new and distinct features.
Earlier versions had simple navigational options, while *Karnaugh* now has increased supportive learner control; its hierarchical navigation allows selection of branches. To orient users, up-front information explains the navigation options and the lesson structure. Novice users are shown a display giving a bird’s view of the contents.

The original *Background knowledge* section consisted only of a test. Now it has informative subsections on binary numbers, logical expressions, truth tables, logic circuits and Boolean expressions. Worked examples and exercises with meaningful feedback are included. The *Sum-of-minterms* section was completely redesigned and greatly extended. Most examples and exercises in the *Karnaugh diagrams* and *Simplification of Boolean expressions* sections were not changed, but more were added, as well as supplementary tutorial matter. Each section ends with a graphical summary. The test at the end, in the form of a game, was taken from the first version.

In particular, the look-and-feel changed completely as HCI aspects were improved in line with current practices. The evaluation of another CAI re-development [6] had identified some inadequacies. In an extended action research approach, cognizance was taken of these issues and new features were included, offering different functionality to new and previous users. Furthermore, hot-word hyperlinks to definitions were inserted in tutorial segments, examples and exercises. Students had wanted to choose the degree of difficulty of exercises, so a multi-option button was developed (lower left corner of Figure 4), which allows users to choose theoretical information (I), worked examples (E) or, in the context of exercises, do basic (QB) or complex questions (QC). This permits different ways of use at different stages of learning. By default, a learner can do all the options by merely using the <Forward> button and this is the approach expected from novice users. In some cases, the feedback after errors includes a <Help> link.

Due to its rigid computational domain, the learning theory foundation of *Karnaugh* is mainly objectivist, using a behaviourist stimulus-response-reinforcement approach. It also combines paradigms as it sets out to support true insight and cognition, and to anchor learning in authentic contexts. Concepts are taught by multiple perspectives on a theme, using text, figures, graphics, evolving animations, and examples. This approach supports learning gain. Figure 2 shows how a question that was answered incorrectly by a learner, receives feedback explaining why it is wrong. Figure 3 displays colour-coded feedback following a wrong answer. The boxed ‘QB’ and ‘A’ are icons indicating a basic question and a response to the answer respectively.

In a novel analogy, a soccer player character provides information and informality after complex sections. Following complex sections, screen displays present soccer activities – e.g. a soccer player bouncing a ball on his head or scoring a goal while giving commentary – to help users take a break. Figure 4 shows clips of such screens, depicting the theme character. It also shows the distinct multi-option button in the lower left-hand corner where the learner can choose tuition information, examples, or exercises with the option of basic or complicated questions. After completing any of the options, the user can use the button and make another choice. A Karnaugh diagram is a 2-D representation of a 3-D spherical phenomenon, for example, the left side of a Karnaugh diagram should, in fact, be joined continuously to the right. Hence the significance of the ball, since a soccer ball is a spherical analogy subdivided into blocks. The soccer player character contributes by providing information and participating in meaningful learning activities.
5. EVALUATION FINDINGS

Formative and summative evaluations have been conducted throughout Karnaugh’s lifecycle. Comprehensive evaluation was done on the original version (V1), as its processes and exercises were tested during development. This paper concentrates on further evaluations, formative and summative, on the 2005 redevelopment to examine, improve and expand the product. The UEMs used in two action research cycles (Fig. 1) to plan responses and commence new cycles, were heuristic evaluation (HE) by the designer’s peers; questionnaire survey evaluation by end users (students); and interviews with students. Karnaugh V2.1 underwent HE by expert peers prior to release, leading to V2.2, which was evaluated in a learner survey, resulting in V2.3. After a year of use, the same evaluation processes were repeated, leading to V3.1 and V3.2 respectively. Finally, an interview survey was done with a few students. By this time the cycles had closed in and the system was virtually problem-free. Rather than repetitive reporting in a sequential format, the findings of the two HEs are integrated in Section 5.1, likewise the discussion of the two learner surveys in Section 5.2.

An evaluation requires a UEM and a set of criteria. Various approaches exist for evaluating usability and effectiveness of educational software and web-based learning environments, for example, Albion [1] and Ardito et al. [3]. Squires and Preece [17] were pioneers of criteria for investigating learning technologies. They adapted Nielsen’s [14] usability heuristics by integrating usability with learning issues, generating a set of principles for ‘learning with software’. These heuristics for inspecting educational software form the basis of the criteria used in the present study.

5.1 Squires & Preece’s Heuristics for ‘Learning with Software’

Using the concepts of cognitive authenticity, contextual authenticity and socio-constructivism, Squires and Preece [17] converted Nielsen’s classic usability heuristics to eight criteria that integrate usability and learning factors for predictive evaluation of educational software prior to use. Six of them (slightly amended) were used in the present study, supplemented by Criteria 9 and 10 [6], generating a set of criteria appropriate for analysing e-learning tutorials by predictive heuristic evaluation and by user questionnaire surveys after use of the application:

1. **Match between designer & learner models**: Does the application represent cognitive tasks in ways that support the development of a learner model consistent with the designer model?
2. **Navigational fidelity**: Evaluators should consider navigation structures, aesthetics, and the effectiveness of the representation.
3. **Appropriate levels of learner control**: This relates to the balance between learner control, self-direction, customization, consistent protocols, and system responsibility.
4. **Prevention of peripheral usability errors**: There is a relationship between domain complexity and error prevention. Although cognitive errors are part of the learning process, peripheral usability-related errors should be anticipated and avoided.
5. **Understandable and meaningful symbolic representation**: Representation forms, symbols and icons should be appropriate; interfaces should present low cognitive demands; learners should not have to remember interaction techniques. Names of learning objects should come from the subject domain and be consistent.
6. **Personally meaningful forms of learning**: Learning should be supported by multiple representations that support different learning styles and meta-cognition. The software should be used along with other learner support materials. (Criterion 6 was not used in this research.)
7. **Cognitive error recognition, diagnosis and recovery**: Cognitive errors are part of learning, but techniques such as scaffolding and bridging should be used to promote the recognition–diagnosis–recovery cycle.
8. **Match with the curriculum**: The software and the curriculum should correspond. (Criterion 8 was not applicable here, since Karnaugh was custom-designed for the curriculum.)
9. **Distinctive features**: Custom-built environments should have unique features to support the particular requirements of their content and context.
10. **Capacity of the system to engage learners**: E-learning environments should motivate learners and hold their attention.

5.2 Heuristic Evaluations by Experts

Heuristic evaluation (HE) [8, 14, 15] is an inspection technique developed by Jakob Nielsen and Rolf Molich, in which expert evaluators examine a prototype or operational system, using a set of guidelines or usability principles called heuristics. In participative AR, the designer asked peers to serve as expert evaluators of Karnaugh. Six evaluated it after its redesign in 2005; five of them subject-matter experts (SMEs), while one was a SME and a usability specialist, a so-called ‘double expert’. Seven others evaluated it in a second HE after its release; four were SMEs and three were double experts. Of these thirteen, eleven teach various levels of Theoretical Computer Science and two are postgraduate students. Reflection on the first HE led to several responsive changes, but the second resulted in very few. In addition, a language editor was guided through the lesson, serving as a fourteenth evaluator.

The expert evaluators used the Squires and Preece criteria and based their inspection on a questionnaire similar to that used by the students (see Section 5.3). They worked through the lesson comprehensively, simulating students’ activities. The main aim was to identify problems in the subject-matter, interfaces, usability and navigation. As explained, the two HEs occurred in different AR cycles, but are discussed together. Table 1 summarises the HEs, showing a decrease in the number of problems identified from forty-two in the first HE to only fourteen in the second.

Although the control and usage patterns of Karnaugh are based on traditional, rather behaviourist, CAI architecture, the experts agreed that they function effectively. The critiques suggested some additional functionality and minor modifications to the control structure. In response to the first cycle, some exercises and information were changed to be clearer and more useful. Usability was further enhanced, technical corrections were made, and language usage was improved.
### Table 1: Problems identified in heuristic evaluations

<table>
<thead>
<tr>
<th>Nature of problem</th>
<th>Problems identified</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subject matter:</strong></td>
<td></td>
</tr>
<tr>
<td>Inadequate feedback to errors.</td>
<td>17 (6 experts)</td>
</tr>
<tr>
<td>Further content-related explanations required.</td>
<td></td>
</tr>
<tr>
<td><strong>Mathematical errors:</strong></td>
<td></td>
</tr>
<tr>
<td>Errors in mathematical syntax.</td>
<td>6 (1)</td>
</tr>
<tr>
<td>Data type of input is not always validated.</td>
<td></td>
</tr>
<tr>
<td><strong>Usability errors/problems:</strong></td>
<td></td>
</tr>
<tr>
<td>Input options overlooked by designer.</td>
<td>12 (4)</td>
</tr>
<tr>
<td>Inconsistent use of buttons.</td>
<td></td>
</tr>
<tr>
<td>Responses that conceal text.</td>
<td></td>
</tr>
<tr>
<td>Position of cursor not adequately highlighted.</td>
<td></td>
</tr>
<tr>
<td><strong>Usability in terms of information:</strong></td>
<td></td>
</tr>
<tr>
<td>Inadequate info about operations available.</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Distinction between functionalities for new and former users not explained at start of lesson.</td>
<td></td>
</tr>
<tr>
<td><strong>Control:</strong></td>
<td></td>
</tr>
<tr>
<td>Exit facility is unavailable while user does info sections, examples or exercises.</td>
<td>5 (4)</td>
</tr>
<tr>
<td>In one case, options entered could not be changed.</td>
<td></td>
</tr>
<tr>
<td>There are system restrictions in one exercise and with regard to minimisation of Karnaugh.</td>
<td></td>
</tr>
</tbody>
</table>

**Total number of problems identified:** 42 (6 experts) 14 (7 experts)

With regard to the criteria listed in Section 5.1, general opinions are summarised, not necessarily distinguishing between the two HEs:

1. **Match between learner and designer models:**
   - The experts (peers) were very positive, firmly believing that the tutorial’s approach and didactic content would help students to correctly comprehend the theory and applications of Karnaugh diagrams.

2. **Navigational fidelity:**
   - The expert evaluators had no problems in navigating right through the tutorial, finding it to be well structured, easy to learn, and easy to operate.

3. **Appropriate learner control:**
   - Over 80% of the evaluators felt in control and able to decide what to do next. Similarly, it was clear which button or menu item would give the required operation. There were a few requests for an `<Escape>` or `<Minimise>` button on each frame. During question answering and test taking, it is inadvisable for students to escape, since the didactic purpose is completion. The only control available in tuition frames and in worked examples, is `<Forward>`. These involve just a few sequential frames at a time and the designers felt that this should not be changed. In all other frames it is possible to return to the menu to choose a sub-menu or to exit. In the first HE two experts ‘got lost’, but in the second, following improvements, this did not occur.

4. **Prevention of peripheral usability errors:**
   - In both HEs, two evaluators had usability problems. They requested use of the space bar in a situation that enforced use of backspace or tab keys in a certain exercise. As in de Villiers’ [6] evaluation of another UNISA CAI application, some problems occurred when evaluators used operations and keystrokes familiar from other systems.

5. **Meaningful symbolic representation:**
   - The symbols, icons and names were unanimously found to be appropriate and consistently used. Screens were user-friendly and did not cause information overload. One evaluator pointed out a lack of variety in the text; he noticed similar phrases used repetitively in instructions, in questions, and in feedback.

6. **Cognitive error recognition, diagnosis and recovery:**
   - Cognitive errors could be recognised and corrected by using the feedback. Evaluators confirmed the value of learning from mistakes.

7. **Distinctive features and engagement**
   - The general feeling was that the lesson is appealing and engaging. Of the thirteen expert evaluators, eleven found the screen designs attractive. There was not consensus on the colours used. A third of the experts liked them, with the rest taking neutral positions. They all identified the significance of the soccer ball and its role in the lesson. Most felt that the soccer player provided light relief and a break from cognitive activities, although one found him irritating. General comments were positive: ‘I am impressed with the smoothness of the system and the amount of work that went into it.’ / ‘I like it’ / ‘A very intensive and thorough lesson ... helpful to students’. ‘It is great! Congratulations!’ An experienced double expert said, ‘I rate Karnaugh highly in terms of learning and usability’. Moreover, he immediately grasped the significance of the spherical soccer ball as a continuous 3-D analogy of a Karnaugh diagram. He also appreciated the ‘feeling of fun and relaxation’ it gave to the interaction experience.

### 5.3 Questionnaire Survey among End Users (Learners)

Using Criteria 1-5, 7, 9 &10 from Section 5.1, evaluation questions – two to four per criterion – were generated in the form of statements to be rated on a Likert scale. Some had open-ended sections for elaboration. Many learners are not first-language English speakers, so questions were phrased simply, using basic terminology. The final sections investigated users’ attitudes towards Karnaugh’s distinctive features, such as the soccer theme. We do not have figures on the total number of students who used Karnaugh, since it was voluntary to complete the questionnaire. This study analyses responses to questions from the 34 questionnaires returned in 2006 and 28 in 2007. The 62 participants were a good representation of COS113 learners in terms of age (from 18 to 44), gender, cultural group and full-time / part-time students. Only five were using computers for the first time; 60% (2006) and 46% (2007) were simultaneously studying a programming module; 41% (2006) and 50% (2007) used computers at work.

Certain 2007 students were phoned for follow-up telephone interviews (Section 5.4) and this led to the identification of flawed data: some of them admitted they had completed the
questionnaire without first going through Karnaugh. Corrupt data is not uncommon in questionnaire surveys, but is seldom pinpointed. We were concerned and decided to determine the scale of the problem by phoning most of the participants. It turned out that seven of the 2007 participants had shortcut the process, but only three of the 2006 participants did this. Since the data was deliberately entered in a way that preserved anonymity, it was not possible to remove the offending questionnaires, meaning that up to 25% of the 2007 questionnaire data is flawed and up to 10% of the 2006 data. Due to the small-scale impact on this study as a whole, we continued to use this survey data. A secondary result of this occurrence is that we have obtained data relating to (un)ethical aspects.

Findings of the two surveys are reported under the Squires and Preece (S&P) [17] categories and were used to make minor responsive changes to the design and implementation, leading to V2.3 and V3.2 respectively. The 2006 and 2007 groups were subsequently compared with respect to each of the evaluation statements using Fisher’s exact test at the 0.05 level of significance. Significance was attained when \( p \) is less or equal to 0.05, with \( p \) being the probability that the data derives from a distribution where the null hypothesis of ‘no difference between groups’ holds. Not all \( p \)-values and evaluative statements are reflected in the following tables.

Match between learner and designer models: The way I understand the theory of Karnaugh diagrams (Criterion 1)

Ratings about cognitive effectiveness were very positive. In both cohorts about half the students found some exercises ‘really complicated’, while the other half did not (evaluative statement 2 below), indicating balance within each group.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Maybe</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Doing exercises in Karnaugh helps me understand the theory of Karnaugh diagrams.</td>
<td>2006: 14 (41%)</td>
<td>14 (41%)</td>
<td>5 (15%)</td>
</tr>
<tr>
<td>2. Some of the exercises are really complicated.</td>
<td>2006: 3 (9%)</td>
<td>13 (38%)</td>
<td>11 (32%)</td>
</tr>
<tr>
<td>3. With the teaching from Karnaugh I managed to get most exercises right.</td>
<td>2006: 6 (18%)</td>
<td>19 (56%)</td>
<td>6 (18%)</td>
</tr>
<tr>
<td>4. The elaborations and explanations help me to understand how Karnaugh diagrams function.</td>
<td>2006: 15 (44%)</td>
<td>15 (44%)</td>
<td>3 (9%)</td>
</tr>
</tbody>
</table>

Navigational fidelity: Working my way through Karnaugh (Criterion 2)

Responses to the evaluation statements below described the tutorial as easy to learn, easy to use, and the structural paths as easy to navigate. With respect to orientation within the environment (evaluative statement 6 below), the 2006 and 2007 groups differed marginally \( (p = 0.068) \) with the 2007 participants being slightly less sure of their orientation within the tutorial.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Maybe</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. When I use this lesson, I know what parts I have done and what I still need to do. ( (p = 0.068) )</td>
<td>2006: 13 (38%)</td>
<td>19 (56%)</td>
<td>0</td>
</tr>
<tr>
<td>7. The lesson is easy to operate.</td>
<td>2006: 7 (21%)</td>
<td>21 (64%)</td>
<td>4 (12%)</td>
</tr>
<tr>
<td>8. It is easy to learn how to use Karnaugh.</td>
<td>2006: 8 (23%)</td>
<td>16 (47%)</td>
<td>6 (18%)</td>
</tr>
</tbody>
</table>

Appropriate levels of learner control (Criterion 3)

In general, students were satisfied. In most cases 80% or more selected ‘Strongly agree / Agree. Only one student requested an <Exit> facility on each frame (open response after evaluative statement 12), although several expert evaluators requested this. A possible reason could be that the academics were very busy and used the tutorial between other work-related issues, while learners were more able to focus on study.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Maybe</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. I am in control of the lesson and able to choose what to do next.</td>
<td>2006: 8 (23%)</td>
<td>20 (59%)</td>
<td>3 (9%)</td>
</tr>
<tr>
<td>12. I am able to escape whenever I am not in the process of doing an exercise.</td>
<td>2006: 3 (9%)</td>
<td>23 (67%)</td>
<td>4 (12%)</td>
</tr>
<tr>
<td>13. When I want to take an action or perform an operation, it is clear which button to use or menu-item to select.</td>
<td>2006: 11 (33%)</td>
<td>19 (58%)</td>
<td>2 (6%)</td>
</tr>
</tbody>
</table>

Prevention of peripheral usability errors: ‘Types of mistake’ (Criterion 4)

This section relates to usability errors, not to cognitive errors (Criterion 7). The latter should be permitted, but usability errors and perception errors should be avoided. As was the case with the experts, some students experienced a usability problem by pressing a wrong key where the instructions clearly state that the space bar must not be used. This cannot be changed due to a system restriction, so we highlighted the instruction in V3.1. Errors identified in the 2006 open-ended section were rectified.
leading to better ratings in 2007. As occurred in the expert evaluation, quite a number of participants made mistakes by trying to use functions they knew from other systems (evaluative statement 16 below). This shows the tendency of generalisation and, within the constraints of the development environment, that designers should adhere to norms.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Maybe</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. I made mistakes while using Karnaugh, i.e. usability problems.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006: 10 (30%)</td>
<td>9 (27%)</td>
<td>12 (37%)</td>
<td>2 (6%)</td>
</tr>
<tr>
<td>2007: 5 (18%)</td>
<td>7 (25%)</td>
<td>12 (43%)</td>
<td>4 (14%)</td>
</tr>
<tr>
<td>16. I made mistakes because I used operations and keystrokes I know from other systems.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006: 9 (27%)</td>
<td>7 (21%)</td>
<td>12 (37%)</td>
<td>5 (15%)</td>
</tr>
<tr>
<td>2007: 4 (15%)</td>
<td>5 (19%)</td>
<td>12 (44%)</td>
<td>6 (22%)</td>
</tr>
</tbody>
</table>

Meaningful symbolic representation: Symbols, icons & names (Criterion 5)

Although a high percentage of respondents found the screens easy to read, there was a significantly \((p = 0.038)\) stronger feeling amongst 2007 participants that ‘there is too much information on the screens’ (evaluative statement 19), due to six who chose the middle option, ‘Maybe’. This might be due to the additional explanatory notes included in the 2007 versions (V3.1 and V3.2) or it could be due to flawed data from the invalid questionnaires.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Maybe</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>17. The screen layouts are easy to read.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006: 15 (45%)</td>
<td>17 (52%)</td>
<td>1 (3%)</td>
<td>0</td>
</tr>
<tr>
<td>2007: 7 (25%)</td>
<td>17 (61%)</td>
<td>3 (11%)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>18. The symbols and names that represent the objects are used consistently in Karnaugh.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006:11 (3%)</td>
<td>20 (61%)</td>
<td>2 (6%)</td>
<td>0</td>
</tr>
<tr>
<td>2007: 8 (29%)</td>
<td>16 (57%)</td>
<td>4 (14%)</td>
<td>0</td>
</tr>
<tr>
<td>19. There is too much information on the screens and it confuses me. ((p = 0.038))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006: 3 (9%)</td>
<td>0</td>
<td>18 (55%)</td>
<td>12 (36%)</td>
</tr>
<tr>
<td>2007: 3 (11%)</td>
<td>6 (21%)</td>
<td>11 (39%)</td>
<td>8 (29%)</td>
</tr>
</tbody>
</table>

Cognitive error recognition, diagnosis and recovery: Recognising mistakes and recovering (Criterion 7)

These errors differ from the usability errors of Criterion 4. Cognitive errors are part of learning. They occur due to domain complexities, misconceptions and pitfalls, and the aim of the feedback is to rectify them. The feedback obtained high praise, with around 90% choosing Strongly agree / Agree. Examples of open responses: ‘It gives you the opportunity to re-evaluate your answer in order to find an alternative.’ / ‘I agree with the amount of feedback.’

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Maybe</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>20. The feedback (system response) to incorrect answers is useful.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006: 13 (39%)</td>
<td>16 (49%)</td>
<td>4 (12%)</td>
<td>0</td>
</tr>
<tr>
<td>2007: 9 (33%)</td>
<td>18 (67%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Distinctive features, motivation and engagement (Criteria 9 and 10)

Participants liked the aesthetics and the colours, and most enjoyed the informal theme of the soccer player and his ball.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Maybe</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>22. The screen designs are attractive.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006:7 (21%)</td>
<td>20 (61%)</td>
<td>5 (15%)</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>2007:9 (32%)</td>
<td>15 (54%)</td>
<td>4 (14%)</td>
<td>0</td>
</tr>
<tr>
<td>23. I like the colours in Karnaugh.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006: 7 (21%)</td>
<td>20 (61%)</td>
<td>5 (15%)</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>2007: 7 (25%)</td>
<td>14 (50%)</td>
<td>7 (25%)</td>
<td>0</td>
</tr>
</tbody>
</table>

With relation to the soccer ball theme, 47% of the 2006 participants grasped that it represented a Karnaugh diagram, but in 2007 only 22% did. In open responses, learners commented on the soccer activities: ‘It allows a student to associate Karnaugh with a fun activity.’ / ‘Gives you a break and clears your mind so that you can concentrate better on the tasks.’ / ‘When I was confused, the soccer player also showed that confused face. This took away a lot of stress because you are not the only one confused. He is like a buddy that shares the same emotions’. On the other hand, one stated ‘Because of time constraints I did not pay much attention to the activities.’ An interesting comment: ‘Since we are hosting the 2010 World Cup, I thought that the syllabus is also having soccer fever!’

With regards to the tuition, there were varied comments: ‘Karnaugh is a brilliant tool. I personally feel that all CAI lessons should include more examples.’ / ‘It is useful to be able to choose between theory and the different difficulty levels of examples.’ / ‘I was impressed by the colours used to explain things.’ / With regard to the feedback to incorrect answers: ‘It boosted my confidence in tackling the assignment.’ / ‘Helps you to note other points you didn’t understand when doing the theory – lets you think out of the box.’ One student commented: ‘I was not satisfied with the navigation buttons because they are not everywhere throughout the lesson.’ and another ‘Karnaugh’s theory part needs more explanations.’ Some learners were extremely positive: ‘I was actually reluctant to stop using it (presented so nicely that it is a pleasure using it).’ / ‘The ‘game’ in the end was extremely exciting and motivating.'
attempted each question seriously and it paid off.’ / ‘Brilliant work indeed.’

5.4 Interviews

Telephonic interviews were done with a sample of seven students on issues not fully addressed in the questionnaire. They were a representative, heterogeneous group in terms of gender, age and full time/part-time status. The interviews were semi-structured, in that core questions were asked and notable or unanticipated responses were followed up.

Did you use the multi-option feature that lets you choose between information, examples, basic exercises or complex exercises?

Participants responded positively, acknowledging the utility of the feature. One said that she mainly used the <Forward> button so as to do all the activities, but used the multi-option when she needed to ‘refresh her memory’ on specific aspects. This confirms its value in helping students use Karnaugh in different ways at different times, e.g. in practicing exercises before exams.

What do you think of the CAI experience overall?

The lesson was said to be ‘interesting’, ‘helpful’, ‘fun’ and ‘challenging’. One student particularly enjoyed working through the examples; another found the exercises ‘very practical, they gripped my attention’. A student having his first-ever encounter with CAI was surprised to find how user-friendly it was.

The interviews highlighted the value of Karnaugh as supplementary tuition material. Issues not resolved by the study guide alone, were solved by CAI. We confirmed the value of multiple means of presentation and different perspectives on Karnaugh diagrams. One student found that the soccer theme and animated round ball continually reminded him that Karnaugh diagrams are 3-dimensional, which is not always perceived from printed representations.

Tell us about problems you encountered in using ‘Karnaugh’.

Very few problems emerged. One student found it so helpful that she asked for the background and teaching content to be extended even further.

How did Karnaugh contribute towards your answering of exam questions?

Participants were positive that the e-learning tutorial contributed to comprehension of Karnaugh diagrams. One specifically stated how it had helped with ‘making the groups in the diagrams’. Another described how she had originally struggled with the diagrams, but that the CAI tutorial had been ‘a practice session before the exams’. Another said that he would not have been able to do that section in the examination at all, were it not for the CAI experience.

5.5 Conclusion

The answers to the two research questions are concisely summarised:

1. How can the design, redesign and evaluation of e-learning be supported by an action research (AR) approach?

The action research approach to design, development and multiple evaluation is described explicitly in Section 3 and is the implicit ‘golden thread’ throughout Sections 4 and 5. The researcher-designer took participative ownership of the study, and AR demonstrated its value as input was continuously fed into the cycles in the form of corrections and improvements to Karnaugh. The iterations gave rigour to the study. Karnaugh evolved through five variants, culminating in a version which is virtually free of problems and of great value to its target group.

2. What kind of findings emanate from the various evaluation methods?

The S&P [17] evaluation framework has high utility in evaluating CAI (whereas newer frameworks are aimed more at Web-based learning). The criteria served effectively to identify both the educational worth and usability of Karnaugh, as well as issues that required correction or refinement.

Different UEMs played complementary roles. There were two heuristic evaluations by experts – one that eliminated pre-release problems and another done on V1.3. They proved to be a fast and effective means of finding and correcting issues in e-learning applications.

Interviews with students elicited valuable spontaneous information that is difficult to obtain from rigid surveys. In this case, the interviews also unveiled unethical completion of questionnaires by some participants who did not have the required background.

User-based questionnaires supplemented the data from HEs, but were less valuable in pin-pointing problems. Their worth lies in the positive responses and qualitative open-ended data confirming that Karnaugh is on track in supporting its users. The flawed data encountered does not invalidate the overall value of this multi-faceted longitudinal study, since it relates to one aspect only. The lesson to be learned is that questionnaire administrators should take explicit measures to guard against such inconsistencies. For example, a questionnaire could specifically enquire up-front whether subjects have done the required background work, and if not, request that they proceed no further.

The participants of 2007 achieved slightly higher marks in the exam questions relating to Karnaugh than the participants of 2006 ($p = 0.766; 57.1\%$ versus $55.6\%$). Overall, the percentage of passed-over-written for the entire exam was $59.43$ for the 2006 examination group and $52.26$ for the 2007 group. In general the 2006 cohort was stronger than the 2007 cohort.

This study shows that CAI lessons developed at UNISA, such as Karnaugh with its good usability, high interactivity, insightful tuition, and excellent feedback to exercises, has a role to play in the world of the Web and Net.

6. ACKNOWLEDGMENTS

We gratefully acknowledge the expertise of the programmers, MALENE LE ROUX and ESTELLE DE KOCK, and the graphics and animation by TERSIA PARSONS. We appreciate a helpful critique of this article by our colleague TERTIA HÖRNE.

REFERENCES


Barriers to students’ use of electronic resources during lectures

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ABSTRACT
This paper highlights one of the barriers for implementing an educational technology policy at a higher education institution. As more courses use a Learning Management System (LMS), learning resources are electronic and an increasing number of students are using Notebook computers for accessing electronic resources and reading on the screen. However, there is a dichotomy between provision of electronic resources and students being allowed to use Notebooks during classes. This paper explores lecturers’ ambivalence towards student use of Notebooks during classes and illustrates how such perceptions are becoming a barrier to successful implementation of an educational technology policy.

CATEGORIES AND SUBJECT DESCRIPTORS

GENERAL TERMS
Human Factors, Theory, Management

KEYWORDS
Electronic resources, e-learning, resource constrained environments, Learning Management Systems, Structuration

1. INTRODUCTION
Mobile devices have potential to enhance learning and transform pedagogy [3, 7, 8, 9]. Some of the uses in education include their use by teachers for writing process pedagogies [7], and by students for note taking, quick accessing of learning materials and applications and finding relevant materials [3].

Kuh and Vesper’s [5] study on the relationship between student use of computers and cognitive and development gains reported that students who used computers more often outscored those with low use on every developmental gain like writing clearly, ability to learn independently, and understanding other people and science. Despite these affordances there are several barriers to implementing e-learning at institutions. Jordan and Jameson [4] outline barriers for staff on the path to an e-University as: institutional distractions and lack of focus; perceived unclear leadership; models of learning selected inappropriate for e-learning; e-University project perceived as a threat by some e-critics or not considered at all by many; staff involved already overloaded; risk to staff of poor e-materials, lack of support and training.

Van der Merwe and Mouton [10] report that lack of commitment to change by faculty members is a result of: the time investment needed to learn how to integrate Information and Communication Technologies (ICTs) effectively into teaching and learning activities; the time it takes to develop, maintain and participate in online learning activities; lack of incentives and rewards for teaching and learning in general; lack of reflection on teaching and learning itself; and lack of understanding of the potential benefits of ICTs for teaching and learning activities. In this paper, reflections on teaching by educators are used to unravel the problem of access to electronic resources by students who own Notebooks but cannot be allowed to use them in class. This paper argues that as institutions move towards wide use of learning management systems, an increasing amount of resources is available electronically, and students will be expected to bring to class electronic resources, to annotate readings and take electronic notes. Thus, the question we sought to address was: To what extent is the educators’ ambivalence to students’ use of Notebooks in class a condition of a lack of understanding of the benefits of ICTs for teaching and learning.

2. LITERATURE REVIEW
The use of a computer as a medium for reading and interacting with course materials offers advantages such as efficient...
searching, convenient storage of large amounts of information, and navigation via hyperlinks that connect sections of text [6]. Graetz [3] argues that the migration to the web of content traditionally delivered by instructors in lecture format is helping shift the function served by brick and mortar classrooms from information delivery to collaboration and discussion.

This paper contends that in resource constrained environments such as developing countries where students have limited access to the Internet, the value of web content is evident when learning resources are downloaded and read offline. This means that students do not need to be online to read resources nor incur unnecessary printing costs as they can read resources from standalone Notebooks. Most lecture rooms at this contact university are not wireless hotspots.

3. CONTEXT

The University of Cape Town (UCT) is regarded as a (transformative) international African university (UCT Mission Statement) whose student clientele is drawn not only from different African countries but the world over. In 2006 a total of 21,562 students enrolled at UCT1. Consistent with its agenda to adhere to the global agenda of transformation, UCT has strived to retain a balance between diametrically different values of maintaining global educational standards on the one hand, and retaining a bona fide African institutional identity on the other, thus putting this giant institution in an ambivalent position fraught with both opportunities and challenges. One such opportunity has been UCT’s visibility as early adopter of modern technologies such as the open source Sakai learning management system, locally branded as ‘Vula,’ among others. UCT also provides burgeoning access to online databases, printing facilities, digital archives and online search for books in libraries has since become the norm rather than an exception for both students and researchers alike. The challenge, however, lies in the receptivity of lecturers to student use of electronic resources during their lecture sessions.

4. THEORETICAL FRAMEWORK

The question of educators’ ambivalence to students’ use of Notebooks is about rules and resources on the one hand, and reproduction of relations between actors or collectivities organised as social practices and conditions that govern the continuity of transformation of rules, on the other. To this end, the study draws on the Theory of Structuration. The Theory of Structuration takes the view that human action is an expression of a mutual dependence of structure and agency [2]. According to [2], structures are about rules and resources but rules and practices only exist in conjunction with one another, hence the duality of structure. In Figure 1, the duality of structure is illustrated.

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>Rules and resources organised as properties of social systems. Structure only exists as ‘structural properties’</th>
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<tbody>
<tr>
<td>SYSTEM</td>
<td>Reproduced relations between actors or collectivities, organised as regular social practices</td>
</tr>
</tbody>
</table>

Table 1: Definitions of structure, system and structuration
(Source: Giddens, 1979: 66)

1 http://www.uct.ac.za/about/intro/statistics/

Our assumption is that Structuration theory will help to uncover structure, system and their structuration through exploration of the interplay between human action and social structures. Giddens [2] postulates that structure forms personality and society simultaneously – but in neither case exhaustively: because of the significance of unintended consequences of action.

5. METHODOLOGY

Twenty students were interviewed on their attitude towards use of Notebooks in class and the extent to which they felt Notebook use enhanced meaningful learning for their courses. Half of these students owned personal Notebooks and the remainder did not. Convenience sampling was used to select students with Notebooks and these were personally approached for the conduct of in-depth interviews. Those without Notebooks were randomly picked on the basis of their sex for in-depth interviews as well. To provide a more informative view of Notebook use, six lecturers in different departments, four of whom taught the interviewed students were also interviewed in connection with their perception of Notebook usage, with particular reference to enrichment of students’ in-class learning experiences. Three in-class observations were conducted for each of the four lecturers’ classes to ascertain the attitudes of these lecturers and their students on the use of Notebooks in class. Each observation lasted the average time of a lecture, which is forty-five minutes.

The research participants were undergraduates and postgraduates from five departments: Information systems; Demography; Education; Health Economics; and Information and Library Studies. The courses in these departments were selected because lecturers made use of the learning management system (LMS) as a medium for distributing electronic resources and by extension some students accessed the resources in class using Notebooks (NB: Few students owned Notebooks).

6. FINDINGS AND DISCUSSION

Interview transcripts of both students and lecturers were analysed. Giddens’ notions of structure, system and structuration provided the analytical framework. To this end, the objective of the analysis was to gain insight into the interplay of rule, resources, actors, social practices and conditions of reproduction. The goal was to move towards understanding the question of educators’ ambivalence to students’ use of Notebooks in class and the extent to which this was a condition of a lack of understanding of the benefits of ICTs for teaching and learning.

In the next section lecturers’ and students’ perceptions are analyzed. For the purposes of anonymity, lecturers are described as masculine with a he or his while students as feminine. These are not necessarily their true genders.

6.1 Analysis of lecturers’ views

The lecturers’ perceptions ranged from selectively allowing use of Notebooks in specific topics in lectures (but not encouraging their use except for one lecturer interviewed), sceptical view instantiated by perceptions of Notebooks as having a detractive effect and feelings that Notebooks were unnecessary for some classes. The following are extracts of the responses from
lecturers when asked whether they allowed the use of Notebooks and whether they felt they could enhance meaningful learning for their students.

L1: I have never thought about how and why Notebooks could be used in the lectures. What I know is that I have a student who is researching on how Notebooks are being used to improve the literacy (writing) skills for Grade 11 classes of a school in the Western Cape. Of course, this school has introduced the use of Notebooks in class because it is one of the posh schools around. But for a university, I have never thought how this could happen.

The lecturer seemed to acknowledge the value of Notebooks in literacy development skills, yet failed to locate the essence of Notebooks in university classes hence his indifference to their use. The fact that he mentioned he has never figured out how they could be appropriated could have two profound meanings. First, that it might be understandable that Notebook use as mediating tools for student learning of his course might be unnecessary or that the lecture space layout could preclude their use even if he wanted to introduce them. Alternatively, this could mean that he could not figure out the pedagogical implications of introducing their use. Aply put, where Notebooks are introduced as tools of constructivist knowledge construction and dialogic interaction, there is far reaching re-engineering of pedagogical processes necessary– renegotiation of the instruction mode, redefinition of the role of the teacher and the emergence of multiple voices from students which could be unsettling/disturbing to contemplate for the lecturer. Another lecturer when asked the same aforementioned question snidely remarked:

L2: That would depend on what it was used for. I mean if it is used for the same purpose as a hand written, you know if it is used to take notes like pencil and papers, then I do not see how it is different and that is how it is used. I think it is just used to take notes. I had a Notebook in England when I was a student and I never carried it, never. I didn’t have any need to. Pen and paper to take notes, if I need to take notes. Some students don’t need to take notes, they very solely take notes in lectures, very solely. I would rather listen and engage and if the guy covers something, I would ask them to send me their notes that’s what I will do and I have trained my students to do that also so that they would rather engage than take notes. So I don’t think that universities are going to crush if they do not have Notebooks in the classes. You see if you use a Notebook as a notepad it is absolutely no different than to use a pen and paper. So its kind of a false notion that you have that one is technologically advanced by using a Notebook. It’s not. It’s absolutely no different than to use a pen and paper, it’s the same technology.

The lecturer’s view on student Notebook use in class sounds a bit sceptical and he feels that Notebooks are only being used to replicate what a pen and paper does. While his view of some resounding consonance between the Notebooks and pen and paper as note taking and mnemonic devices could be logical, the same cannot be said if these devices (Notebooks) were Internet networked allowing for the online discursive engagement of students and quick online access to relevant learning material.

What the lecturer seemed not to realise is that Notebooks offer more affordances for collaborative engagement than pen and paper through the exchange/sending of typed text to group members and access to related academic material on the Internet to support established personal perspectives and ideological positions expressed in text. Diametrically different from the aforementioned remarks is another lecturer who gave an encouraging remark about Notebook use in his classes.

L3: We allow them to use Notebooks and there are no restrictions and they can use anything in the lab and in class. While some lecturers could have found them distracting but not with our department. We also allow them to SMS questions to Dynamic Frequently Asked Questions (DFAQ) in class, any time-twenty four hours a day. If they have got a question and they think about it they can SMS right away. The reason for that is that they do not have to wait, they can SMS twenty-four hours a day.

In this class students were allowed to post questions to DFAQ, an anonymous consultative space [11][12][13][14] with a mobile phone interface. Using DFAQ students ask questions and get responses from peers or lecturer. These threaded interactions of posts of questions and responses, generated by students, become resources (artefacts) for future reference by students. The fact that students are allowed even during lectures (in class) to post questions is encouraging and sounds inconsistent with other lecturers who feel that such engagements could be disruptive to the flow of their lectures. One student when asked about her experience of classes particularly the use of Notebooks in class, she highlighted that Notebooks could only be used for specific topics but more often than not they were discouraged.

L4. Well, the lecturer didn’t have the time, in fact it was perceived not convenient for us to work with Notebooks as he would be conducting his lecture since the lectures were more of a one way process where the lecturer would be giving information to students and as such using Notebooks was conceived to obstruct the course of the lecturing process...like he felt we would not be able to pay particular full attention when he would be there displaying be it a method or whatever, in front of us explaining. So for us to be working with Notebooks that was actually discouraged and we did not have the time to be working on our Notebooks.

The fact that the Notebook would split student attention and eye contact between the Notebook and the lecturer was identified in addition to constraints of time, as the reasons for viewing the Notebook as distracting. This shows the dilemma that lecturers often face in introducing Notebooks in class- the need to open up learning opportunities by appropriating the technological affordances of interactive engagement and developing open educational systems receptive to digital technologies on the one hand, and the need for smoothly flowing lectures occasioned by concentrating on the teacher as the main information disseminator (“the sage on the stage”). While lecturers were concerned about the need for innovative use of Notebooks in class, they seemed equally anxious about additional demands for surveillance that were prompted by what they perceived as off-task behaviour. One professor cited this: 

2 DFAQ is a special purpose anonymous consultative tool developed at UCT by one of the authors of this paper.
L5: You want my opinion whether I think it is useful for students to engage with Notebooks in class? My response would be influenced by my understanding of what I thought the students would be doing with those Notebooks. If they were taking notes or summarising notes, I would have no problems with that and that would have to be apparent...and I know how distracting a Notebook can be. If I felt the tool was helping to understand the learning material I wouldn’t be unhappy with it at all... But I think I need to know what they are doing with the Notebooks, what specific function or what value they were going to get from that Notebook. If it is to fiddle round and play notes and crosses and bridges, what’s the other game that they play? Some video games?Yaah, then I won’t be interested.

What is very apparent in the Professor’s utterance is not only the need to optimise the students’ learning experiences with these interactive gadgets but also the tension and dilemma of the occasional need to retain the lecturer’s authoritative voice in the class on the one hand, and the challenge of managing other perceivably flippant activities or off-task behaviours by students, on the other. The professor’s legitimate right to retain the former is evident in his emphasis on the validity of his opinion as an authority figure- “my understanding of what I thought the students would be doing with those Notebooks...and that would have to be apparent... But I think I need to know what they are doing with the Notebooks, what specific function or what value they were going to be getting from that Notebook.”

The complexity of sanctioning perceivably distractive engagements is evident in the latter statement: “If it is to fiddle round and play notes and crosses and bridges, what’s the other game that they play? Some video games?Yaah, then I won’t be interested.”

The same professor also underlined that:

L6: If I need to demonstrate and show something a little bit complicated, I do not want them to be distracted with e-mails or looking at other things. You know, sometimes they get behind and they start fiddling and fussing. So I think distractions computers or Notebooks offer are many, opportunities for distractions like getting meddling up or losing your words or something happens or whatever, there can be a grand distraction... I would also not like the Notebooks to be a distraction to other students who don’t have Notebooks. You know when people are working at a Notebook they matter under their breath and they are doing all sorts of things because technology is not always smooth. So if they were getting flustered, irritated or impatient they would start muttering or what ever, yaah.

The central place of the lecturer in the class is manifested in this transmission mode of pedagogy where he directs and controls the instruction and flow of interactions permissible, and the students’ role is to follow and observe the demonstrations or examples.

Table 2: Structuration Analysis of Lecturers’ Interviews

| STRUCTURE |
|-----------------|-----------------|
| Rules and resources organised as properties of social systems. Structure only exists as | L1: Attribution of use of Notebooks to a well resourced school. Distinction between schools and universities; and the unspoken rule that literacy (writing) skills are what happens at schools and not universities. |

‘structural properties’

| L2: During lectures students listen and engage without note taking. |
| L3: Students set rules of when and where they use ICTs. Provide resources 24/7 as learning cannot be confined to time or space. |
| L4: Students are discouraged from using Notebooks to enable them to concentrate during a lecture which embodies resource investment in terms of educator’s time to prepare. |
| L5: The rule of use is that the educator ought to know that students are doing with the Notebook but seem unaware of how the device can be integrated for teaching and learning. Knows what students should not be doing and not what they should be doing. |

SYSTEM

Reproduced relations between actors or collectivities, organised as regular social practices.

| L1: Social practice is reproduced through operating within what is known. |
| L2: Old experiences as a student are reproduced through expectations of students to do the same. |
| L2: Universities will survive with or without technologies and ICTs are merely tools for doing what we do already. |
| L3: Existing student social practices as evidenced outside the classroom are allowed to reproduce in class. |
| L4: Reproduce notions of a lecture room as a space for one way communication from educator to learners. Interaction with learning resources, which Notebooks enable, is not seen as a lecture room activity. |
| L5: Quest to maintain attention by removing distracters aims at reproducing relations of teacher-learner and not learner and learning. |
| L6: Reproduce silence in class when a lecturer is explaining something important. Nothing is said about what should happen any other time. |

STRUCTURATION

Conditions governing the continuity or transformation of structures, and therefore the reproduction of systems

| L1: Not to have thought about how and why suggest unconscious inclination to continuity of status of lectures. |
| L2: A pre-determined use limited to familiar metaphor of pencil and paper thereby seeing normal practices continued in electronic form. |
| L3: Transformation is fostered through support as educators use popular tools among students for teaching and learning. |
| L4: Preconception of a lecture as a place where one person (usually a lecturer) speaks and the rest of the class is “quiet” and Notebook use seen... |
6.2 Analysis of students’ views

Students interviewed echoed the need to change the teaching mode/strategy where Notebooks are used for collaborative student learning, problem solving and engagement with learning resources. One student coined the need for proper time management and for lecturers to wander around the class to keep students focused on the task, if necessary:

S1: When a lecturer adopts the methodology of using Notebooks as part of his teaching strategies he needs to be careful in terms of time management. He needs to ensure that instead of him standing in front of the class he has to be going right round the students monitoring and seeing how they are trying to follow what he is teaching. Where possible, students should make the corrections necessary there and there so that they do not spend a lot of time trying to solve one problem. So the interaction must be more intensified when using Notebooks than when they are doing that one-way lecture system.

The welcoming ambience of students consciously attending to a guest lecture while subconsciously/unconsciously browsing the Internet (for important literature related to that lecture, global affiliations that can leverage their context specific real-life learning experiences on specific lecture topic and instant messaging of students’ reflections of their lecture experiences to peers) could expose exciting opportunities students are dearly missing by silently listening to the lecturer in class. Not only does this academic set up provide insights on the implications of reduced teacher authority as the predominant “authoritative voice” [1] and information hub, but instantiates some rethinking about how innovative pedagogy could be activated in a reconfigured classroom set up involving multiple technology enabled voices.

Despite the popular notion of student empowerment, lecturers also seem to be concerned about student social power and thus there is tension between class discipline and empowerment. When these researchers suggested to one lecturer that Notebooks could be used to access extra online educational material for a writing (literacy) project in class, he retorted:

S2: While the lecturer is lecturing? Show me a lecturer who could be keen to lecture to someone who is not listening, is searching for material. Searching for material while I am lecturing? No! No! No! Maybe it may have to be outside. So when you are talking about technology, you are also envisaging a different manner of transmission…

Similarly, the other Professor also noted:

I do not think it is especially useful to say should Notebooks be used in a classroom? There might be instances where lecturers would say No, it’s not necessary. I am demonstrating things on the board and I don’t need a Notebook, they can just need a pencil and paper to do a mathematical formula. They do not need a Notebook for that. So I think it depends very much on the activity or the task.

It seems this transmission mode has also been internalised by students as they are being taught using this style and their conceptualisation of the lecture legitimises the lecturers’ authoritative voice. Appropriating the lecturer’s voice one post graduate student said:

S3: …Notebooks do not have an actual use in that learning process. Because I do not see the use of a Notebook when I am telling you something. I have come here to tell you A, B, C, D, you would not need a Notebook to hear that. You would only need your ears. You would just listen and maybe I have a handout on that so I would give you a handout for that…

Yet another student doing a statistics based programme (which can not be mentioned for the purpose of anonymity) expressed the importance of Notebooks for student practice in class as the lecturers demonstrate on the board so that their mistakes can be apprehended instantly by the teacher. The student noted:

S4: From my own point of view, the most convenient way would be for us to be using Notebooks in class as we are learning about something- be it a method or a certain technique. For us in (Degree programme mentioned), as we are learning that technique the convenient way would be putting it into practice as he will be teaching us. We have to implement that in practice. But now if he postpones (that is by allowing them to practice in the laboratory after the lecture), it actually creates some problems and we won’t be able to comprehend. So for me, the most convenient way would be to use the Notebooks in class so that we would learn from that practically. He could be giving examples and we could be typing on our Notebooks instead of lecturing separately and then we go to the labs and try that out. That postponement actually creates loopholes in the learning process. The convenient way would be to make the lectures more practical… Basically it goes back to the point that lecturing should be a two way process whereby the lecturer teaches, we face a problem and we tell him there and there and we get feedback. So that two-way process is the most convenient way of learning.

The most disturbing issue is to reduce the complex process of meaningful learning to consumption / acquisition (the first student’s observation). What seems apparent is the ambivalent position with regards the loci and foci of student voice in an interactive learning environment enabled by digital technologies. Lecturers appear to reinforce one way instructive process that could be potentially disempowering on the students’ part as the latter student complains.

Table 3: Structuration Analysis of Student Interviews

| STRUCTURE | S1: i) Students need supervision to stay focused on a task and lecture time would be lost if such supervision was undertaken in class as students use Notebooks.  
| Rules and resources organised as properties of social systems. Structure only exists as ‘structural properties’ | ii) Completion of syllabus and heavy workload is shown as a sign of  
| | | |
progress in learning and use of Notebooks is needed to contribute to this.
S2: Students to listen and not do anything else during a lecture. Looking up electronic resources during class causes unnecessarily disruption and has no place in class.
S3: i) Teacher initiated resources are more valuable than those from student /their peers / technology mediated. ii) Notebooks are not associated with ‘hearing’ or recording of a lecture through it.
S4: The gulf between practice and theory must be closed.

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<thead>
<tr>
<th>SYSTEM</th>
<th>Reproduced relations between actors or collectivities, organised as regular social practices</th>
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<tbody>
<tr>
<td>S1:</td>
<td>Create a more interactive learning environment rather than the traditional one-way communication.</td>
</tr>
<tr>
<td>S2:</td>
<td>Reproduce superordinate-subordinate relations by restricting in -class online access to resources.</td>
</tr>
<tr>
<td>S3:</td>
<td>Continue to use ears to hear and there is no need for technology mediation.</td>
</tr>
<tr>
<td>S4:</td>
<td>Teaching should be a two way communication between a teacher and students, students and resources, and use of Notebooks will allow this to happen.</td>
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<tr>
<th>STRUCTURATION</th>
<th>Conditions governing the continuity or transformation of structures, and therefore the reproduction of systems</th>
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<tr>
<td>S1: i) Change the way lecture time is managed. ii) Foster continuity of lecturer’ role as a controller of learning processes and not as a ‘guide on the side’ of a learner.</td>
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<tr>
<td>S2: Do not see how searching for material during a lecture could be related to a current lecture.</td>
<td></td>
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<tr>
<td>S3: Classes are places to hear and there is no place for technology there.</td>
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<tr>
<td>S4: Use of devices will make lectures more practical and more convenient for students.</td>
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**REFERENCES**


**7. CONCLUSION**

This paper has discussed the extent to which educators’ ambivalence to student use of Notebooks could be attributed to lack of understanding of the benefits of ICTs for teaching and learning. While some limited resources and configuration of lecture space were identified by lecturers as standing in the way of technology mediated interactive teaching and learning, the challenges and tensions of retaining the authoritative voice of these educators in class frequently surfaced as one of the reasons for their uneasiness about students’ use of Notebooks during lectures. Giddens’ [2] Structuration theory was used to show how some of these lecturers’ old experiences are often reproduced when they expect their students to act in the same way as they did in class like seating in silence, observing, handwriting notes or not taking notes at all. As an increasing amount of learning resources are distributed to students electronically, Notebooks mediate access to and engagement with learning resources anywhere anytime. Notebooks are increasingly replacing the traditional student backpacks. Our conclusion is that educators’ ambivalence to students’ use of Notebooks in class is a condition of misunderstanding the implications of electronic distribution of resources and electronic tools at students’ disposal to access, read and annotate the resources. Embodied in such condition of understanding is the need for pedagogical knowledge of Notebooks. The educators’ ambivalence to students’ use of Notebooks in class need not therefore be a barrier to successful implementation of an educational technology policy.

How to Do IT Together: Modeling Group Work for Information Technology

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ABSTRACT

Students of programming need to master group work skills. This paper presents a model for group work in it classrooms based on literature and research done the past couple of years. The model emphasizes the importance of structuring small group work for effectiveness by ensuring that the basic elements of positive interdependence, individual accountability, face-to-face interaction, interpersonal and social skills, and group processing are correctly applied. Assigning particular responsibilities to group members and assessing groups are also addressed. A description of the research methodology and data collection and analysis techniques to be used in the piloting of the model is provided. We describe the training workshops for teachers used, the actual teaching of the model in these teachers’ classrooms, as well as future work envisioned. Finally, the importance of the study is justified and conclusions drawn.

CATEGORIES AND SUBJECT DESCRIPTORS


GENERAL TERMS

Management, Experimentation, Human Factors.

KEYWORDS

Group work, Information Technology.

1. INTRODUCTION

“Information (T)echnology projects are growing in complexity” and size [17]. These days, not only can “(t)eam experiences … be important learning experiences;” [9] but, indeed, “(t)eamwork (have become) essential for software development” [7], “and industry highly values team skills in graduates.” [9].

In order for Information Technology (IT) students to be responsive to these changing requirements of the workplace, while learning programming, they must also develop the necessary social skills. In the IT education milieu, various forms of group learning have been widely researched [1]. These important teaching-learning strategies produce increases in learning skills, improve student motivation and have significant positive effects on student performance and attitudes towards instructional content [1,4]. Many of these advantages also represent transferable skills that influence the ways in which students go about their learning tasks - not only when working together in groups, but also when learning individually.

“(G)roup-based … cooperative learning has many benefits to individual student learning” [6], [13] refer to “(r)esults (which) suggest that cooperative learning with … students can lead to greater cognitive involvement, somewhat greater activation, and higher levels of motivation, including higher engagement, greater perceived importance of the tasks, and more optimal levels of challenge in relation to skill.” [17] believe that during the process of actively thinking and working together to construct problem solutions, group projects “provide students with an opportunity to share (and explore) ideas, learn new concepts, expose different points of view, and experience the satisfaction and challenges of working with others”. “(S)tudents felt that group work is a method that significantly fosters the development of a wider breadth of knowledge through discussion, clarification of ideas; and evaluation of others' ideas.” [6]. Exposure to these kinds of opportunities encourages students to work together well - regarded as to be one of the characteristics promoted by good teachers.

Given the many advantages detailed above, it is, however, vital to appreciate “how teachers may influence small-group interaction.” [19]. “(I)t is imperative that … teachers understand how to structure and monitor meaningful learning experiences for students” [13], that lead to the type of thinking and problem solving that is necessary to involve them in the learning process [4]. Research referred to by [3] demonstrates the need for training teachers in the development and implementation of group learning skills. Such training not only

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adds to the advantages of this instructional approach, but also empowers teachers to help their students in the IT classroom to utilize group work skills effectively.

Research as detailed above demonstrates the learning benefits of group work and shows how it can be a valuable teaching strategy in the IT class. Despite this evidence, we found that it is not commonly used for teaching IT [11]. There is still a strong tendency among teachers to depend on individual teaching strategies for teaching programming skills, favoring individual problem solving and individual practice of programming skills. The research question that will therefore serve to focus this paper is: How can group work be meaningfully integrated into the teaching and learning of programming skills?

For the remainder of this paper, we start our journey towards a model for group work in IT classrooms by offering a literature survey of the essential components of effective group work, and results obtained from our own research on this matter. We then explain how the basic elements of positive interdependence, individual accountability, face-to-face interaction, interpersonal and social skills, and group processing should be structured for small group work to be effective. Assigning particular responsibilities to group members and assessing groups are also addressed. A description of the research methodology and data collection and analysis techniques to be used in the piloting of the model is provided. The piloting of the model in terms of the experiences of groups found that it is not commonly used for teaching IT [11]. There are several reasons for this, including the difficulty in structuring small group work to be effective. Assigning particular responsibilities to group members and assessing groups are also addressed. A description of the research methodology and data collection and analysis techniques to be used in the piloting of the model is provided. The piloting of the model in terms of the experiences of groups found that it is not commonly used for teaching IT [11].

2. LITERATURE SURVEY

2.1 Essential group work components

Those experienced in the use of group work know that simply “placing students in groups and telling them to work together will not necessarily promote cooperation and learning” [3]. Literature (see e.g. [8]) emphasizes the importance of structuring small group work for effectiveness, by ensuring that the following essential components are evident:

1. **Positive interdependence**: “individuals believe they are linked with others so they cannot succeed unless the others do” [8]

2. **Individual accountability**: “each collaborator must be individually accountable to do his or her fair share of the work” (ibid)

3. **Interpersonal and social skills** “such as leadership, decision making, trust building, communication, and conflict management skills” (ibid)

4. **Face-to-face interaction**: group members “must have the opportunity to promote each other’s success by helping, assisting, supporting, encouraging, and praising each other’s efforts to achieve” (ibid), and

5. **Group processing**: “group members discuss how well they are achieving their goals and maintaining effective working relationships.” (ibid).

As was the case for [13], group learning activities in this model were designed to encompass the basic elements of group learning as described above.

2.2 Our previous research

In the first piece of our own previous research that we based this model on, we “discussed teachers’ perception of the use of group work in the IT classroom” [11] by describing “the current situation regarding the implementation of group work in IT classrooms in South Africa, as well as the challenges that IT teachers face when implementing group work.” (ibid). Teachers’ responses indicated that they “did not seem to appreciate the dynamics of group work and the contribution that group work could make to effective learning and teaching in the IT class.” [11].

In another section of the project that was used as basis for the model, we initially investigated IT student teachers’ previous experience of group work by means of a questionnaire [5]. We also reported on a case study of a group of student teachers, who worked together over the course of one semester’s worth of IT modules. An account is given on their preliminary views going into the group work, some of what they experienced during the semester and finally, what they learnt about the assumption of various roles within the group and handling conflict. Analytical discussions of these experiences pointed to ways in which this knowledge can be applied to ultimately support teachers in helping their students to apply group skills effectively in IT classrooms [5].

3. A MODEL FOR GROUP WORK

3.1 Positive Interdependence

According to [3], explicitly structuring positive interdependence in groups is vital for group learning to thrive. The interdependence of group members must be dealt with in such a way that they realize that they cannot achieve success unless all the members of the group achieve success. Mutuality needs to be established in terms of common goals and “benefits from achieving the mutual goals” [8]. Having the completion of the project as a common goal should serve as one of the main factors in uniting group members in a joint effort. This mutual goal should be relevant and convincing enough to overcome students’ possible competing agendas and any conflict that might arise within the group. Peer pressure can also play an important role in encouraging good work ethics and commitment to the project.

Benefits received from achieving the common goal (in this case marks for the project) are usually distributed equally among group members, as this highlights the common fate of group members. Results in a study by [7] indicate “that … the majority of the students prefer that a small portion of the (marks) be allocated based on individual contributions, while the majority … is divided equally among the team members.”

3.2 Individual Accountability

[18] stress the importance of assessing for individual accountability, to ensure that all group members participate. Individual accountability is important for group success, since some members tend to dominate and some to withdraw, unless mechanisms are in place forcing everyone to participate. Individual accountability is established when each group member understands that she/he is required at each cyclic meeting to briefly report on “what he or she has been working on and what progress has been made.” [9]. In this way, the meetings also motivate students to make meaningful progress, so that they have something significant to report. By requiring groups to keep a record of their decisions at meetings, each group member can be held accountable for those parts of the project that the group had agreed was her/his responsibility.

All group members are individually responsible to display their own knowledge and skills with regard to programming by applying these to their parts of the project [13]. Individual accountability is further implemented in the structure of the model in that students also write their class tests and
examinations with regard to their programming knowledge and skills individually [12].

### 3.3 Interpersonal and Social Skills

It is necessary to ensure “that students are trained in the social skills required to promote group interaction” [3]. Students need to be taught how to communicate with each other [10], incorporating the concepts of compromise, participation, interaction and working together well. It is also important to teach group members how to “avoid negative comments, and to present their critiques in a positive light” [14].

During the first period allocated to the project, students are provided with “training in small group processes and effective member roles in order to maximize a group’s success” [12]. This is accomplished by having students participate in various activities and games, one of which “illustrates the elements of proper team organization, namely a clear purpose, a plan, clear roles and (creating appropriate) ground rules.” [2].

The actual ‘planning meeting’ takes place in the second period allocated to the project. During the planning meeting, students are responsible themselves for “creating appropriate ground rules” through discussion within the group [12]. These ground rules govern students’ behavior in the group [3], and are reported on as part of group processing.

Teachers also “need to make sure that the time allocated for” planning the group work (at least one period) is spent in appropriate discussion and thorough planning, as this planning “is important in order for everyone to know exactly what they will be doing.” [5]. Each group should provide an “account of how they had planned their work,” with details written down of things such as the division of tasks between various members. If careful planning is not put into place, a group might take very long to really get started, and spend “too long changing their minds about what to do, and as a result they might not have … enough time to complete projects as initially planned.” (ibid).

### 3.4 Face-to-Face Interaction

Face-to-face interaction is supposed to take place each time the groups meet, as students sit “in their small groups to carry on their discussions” [13] at their cyclic meetings. These present students with efficient ways to communicate with each another and work together in order to make orderly progress. They need to provide “explanations, elaboration, and guidance to help their peers understand how key principles related to” their responsibilities within the project [13]. A situation needs to be created where students realize that effective learning is a shared responsibility, and where they share their resources, provide mutual support and encourage each other to achieve success [18].

### 3.5 Group Processing

“(C)ooperative learning tasks” should be “carefully designed and monitored” to ensure that “students engage more actively in their learning experiences.” [13]. In order to effectively monitor each group’s progress [9], students’ mastery and application of group skills are monitored regularly through both observation by the teacher, “as well as through the use of self- and peer assessments (by students)” detailed with a rubric”, which are “submitted at the end of each cycle” [13]. These assessment reports include items detailing positive contributions from different group members towards the project, possible weak spots displayed, and an indication of the global contribution level for each group member. The reports are then used to provide timely, “more complete and appropriate feedback to students reflective of observations from” their peers and the teacher [9] “about how they are doing as group members” [9].

Those group members who are not always good group workers could at times appear to be bored and don’t interact with their groups [5]. Sometimes their efforts and interest are minimal compared to other group members. It could also be difficult to get and/or hold their attention. They might benefit from realizing that it is important for the good functioning of the group to be willing to listen to the other people in the group and find out what their ideas are. This kind of behavior “reminds us that teachers should not only be trained in how to handle ‘trouble-makers’ in groups, but also how to teach their students how to handle such group members themselves, and any accompanying conflict that might occur because of these ‘unruly’ learners’ behavior.” [5].

If the results of group processing show that some students are “persistently disrespectful or uncooperative”, it is important that “swift corrective actions be taken to correct (such) situations” [9]. Such students could potentially “be required to work alone or among themselves rather than be an undue burden to other students’ team experiences” (ibid). We are convinced that if teachers are well trained in ensuring that these elements are successfully implemented in their students’ groups, “a lot of the identified problems would probably decrease.” [11]. Building in essential components of effective group work as described earlier should enable groups to work effectively “to bring in the required group projects according to specifications” and initial planning [5]. It is important that the teacher carefully design and monitor the pitch of the project: On the one hand, some of the “tasks should provide a challenge to students”, while other tasks “require (the) use of skills that they feel comfortably capable of using to maximize their involvement in the tasks.” [13].

A review of research by [3] confirms that the benefits of group learning are enhanced when group size does not exceed four members, as the possibility of free riding increases significantly with additional members added to the group.

### 3.6 Assigning Specific Roles in the Group

[2] illustrate “that there are several roles necessary for successful team interaction and accomplishment.” The main aim of these roles is to assign different responsibilities to group members [11] and determine how group members are to act and/or function within the group. In this way ‘poor drivers’ can be avoided - they usually have “a dominating personality, … (do) not know how to delegate responsibility and (want) to do all of the work on their own.” [17]. The opposite would be students who become ‘free riders’ – they avoid responsibility and/or do not make contributions, but rather are “more than willing to let other students do (all) the work.” (ibid).

As the responses in one of our own studies indicated “that most teachers only use a leader when assigning learners in groups” [11], students are exposed to some of the “common pitfalls in leading teams” [2], and how to take up responsibility. Since in-service teachers’ responses in that same study indicated that they generally “do not know different roles that can be assigned to (students when) working in groups” [11], this aspect needs specific attention during training workshops.

Students are encouraged to rotate between the different roles what can be assumed within the group, and to record this information as part of their cyclic meeting, e.g. who the leader, scribe etc. was for a specific cycle [9]. The scribe/recordert/secretary is responsible for documenting the group conversation and providing the group consensus solution for the problem [15]. Other positions in a group are the
speaker/presenter, who presents the group’s answer to the class,” and “the facilitator, in charge of encouraging everyone to participate” [11]. The role “of a planner, to outline where and how the group is proceeding through the assignment,” can be added (ibid).

3.7 Assessing Groups

Results from our own previous research conform to some of those by [18], in that many arguments put forward why teachers do not often use groups when teaching IT centre on perceptions that assessment in group context and the administration of group work is difficult [11]. Teachers need access to techniques that they can implement in order to obtain information for the assessment of individual students in the group project situation. One of the queries most often encountered with regard to the assessment of group work (that teachers need extensive training in) is: “How do we assess the contribution of an individual when the deliverables are a team effort?” [7].

This aspect is intricately tied into the elements of positive interdependence and individual accountability mentioned in previous sections. A final cumulative peer assessment instrument is used that explicitly asks “each student to rate each group member on” group skills such as communication and cooperation [9]. A principle suggested by [14] is used when marking group projects: “All members of a group …start with the same grade, but … that grade (then) needs to be adjusted for each member by some percentage that reflects their individual contribution(s) as measured by (their) peer … assessment(s).”

This model for the use of groups is now implemented and tested in South African IT classes. It is therefore piloted in selected schools in Gauteng to determine the effectiveness of the model when teaching programming, as well as to identify possible shortcomings.

4. PILOTTING THE MODEL

We provide a description of the research methodology and data collection and analysis techniques for a pilot case study to exemplify the model.

4.1 Teacher Training

In order to pilot the model, selected teachers are trained in the effective use of group strategies for implementation in the teaching and learning of programming skills in the IT class. This training is in accordance with the model as described in the previous section of this paper, and takes place in a workshop setting.

A pre-test - post-test approach is followed, with teachers involved completing a questionnaire before the training workshop to determine their base knowledge, skills, attitudes and perceptions of group teaching and learning in the IT class. After the training workshop, teachers again complete a questionnaire in order to determine the impact of the training on the same. Due to the small number of participants, mainly descriptive statistical analysis is used.

Workshops are based on a solid theoretical framework for implementing group learning in programming projects, as well as practically applying the knowledge and skills gained. Theoretical and practical aspects are interwoven during the workshop to ascertain that the necessary knowledge, skills and attitudes are acquired in such a way that teachers are able to implement it effectively in their own IT classrooms.

Responses in one of our own previous studies [11] indicated that current IT teachers “lack theoretical knowledge of group work.” “Not only were teachers uninformed, but they did not seem to appreciate the dynamics of group work and the contribution that group work could make to effective learning and teaching in the IT class.” [11]. Ignorance of the possible advantages of group learning strategies could be one of the important reasons why it is generally not used for teaching programming skills. If such teachers were to undergo training, one needs to query them to establish whether this is in fact the case; if so, they need to be made aware of this potential.

4.2 Teaching the Model in IT Classrooms

The selected teachers then proceed to teach programming skills in accordance with their training in group strategies. During this implementation of the model in their classrooms, we ask teachers to complete a short journal entry for each implementation opportunity, detailing their ‘trials and tribulations’ of group teaching and learning. These provide rich qualitative information towards the evaluation of the model.

Teachers are visited regularly by the researchers to discuss challenges that they might be facing, with teachers’ journals forming the starting point for semi-structured interviews. The researchers “also provide technical assistance and information,” as well as “emotional support to help innovators keep up their spirits and their efforts” [16].

Once the pilot study comes to an end in schools, teachers will be asked to complete a final questionnaire. A focus group discussion for teachers is also held as a debriefing meeting to their gain assistance in interpreting the outcomes of the study and “provide a versatile, dynamic source of data directly from participants” [12].

4.3 Future Work

Once the model is piloted, this implementation of the model is evaluated and finalized based on results obtained in the pilot study. A sustainable model is then established for pre-service and in-service teachers, by scheduling training workshops for the broad spectrum of current and future IT teachers. These workshops enable teachers to effectively use group strategies to enhance the teaching and learning of programming skills in their IT classes. Teachers are also empowered to set aside their fears in connection with the implementation of group work.

5. IMPORTANCE OF THE STUDY

As indicated in the introduction, there is a significant body of literature available in IT education, going back a number of years, discussing group work learning and dynamics in programming, software development and computer group projects for university level students. Although the idea of using group learning in IT education is therefore not new [1], given the current widespread use of group learning, it is all the more important that “teachers understand how to structure and monitor meaningful (group) learning experiences for students.” [13].

The model explained in this paper uses existing research findings from empirical studies, and re-enforces current thinking by reconstructing what is already reported in literature. The authors’ claim to originality in this contribution lies in the log of a large amount of descriptive detail of how this knowledge is applied in the development of this model for the application of group work in the IT classroom, which can also be used in the training of teachers. In this way, the ultimate outcome of the research program makes a significant contribution when results are ultimately relayed back to application in schools to support teachers with help for applying group work effectively in their classrooms.

Further potential of this work is situated in the contribution it makes through the collection, qualitative description and
analysis of teachers’ views on their group work experiences in the pilot study. This could contribute as significant work and offer new results and insights that would be of interest to lecturers and teachers across the field of IT education, and thus benefit the SACLA community.

6. CONCLUSION

In light of the scenario as described in the introduction to this paper, students “should be able to work effectively with other members in order to prepare (them) to function effectively in a group context within the work environment.” [11]. Empowering students in this way therefore represents a valuable investment in each of these students’ futures. We remain convinced that “(i)t is therefore of the utmost importance that teachers be trained in effective handling of group work in the IT class.” [11]. This model should enable teachers to understand the dynamics of group work and the contribution that group work could make to effective learning and teaching in the IT class.

7. ACKNOWLEDGMENTS

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Online Continuing Professional Development: Tensions Impacting on the Reflective Use of a Mathematics-friendly Forum Environment

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ABSTRACT

The Internet seems full of potential as a catalyst for the Continuous Professional Development (CPD) of geographically dispersed teachers. Having developed a mathematics-friendly online discussion forum environment, we investigated the personal and situational tensions that impacted on the use of this forum environment as a reflective tool for the CPD of advantaged and disadvantaged mathematics teachers in the South Africa context of disparities. Using elements of Grounded Theory and Activity Theory in a Case study approach, the research identified various tensions that impacted on the use of the environment.

CATEGORIES AND SUBJECT DESCRIPTORS

H.1.m [Miscellaneous]

GENERAL TERMS

Your general terms must be any of the following 16 designated terms: Documentation, Design, Human Factors, Theory.

KEYWORD

Online Continuous Professional Development, mathematics-friendly forum,

1. INTRODUCTION

In 1994/1995, South Africa became part of the largest and most ambitious international study of mathematics and science ever undertaken by the International Association for Educational Achievement (1998). The Third International Mathematics and Science Study (TIMSS) involved 41 countries and half a million pupils. South African pupils performed particularly poorly in mathematics in comparison with other participating countries.

One of the issues where the data suggested action may be appropriate and where it seems feasible, was on mathematics teacher preparation, especially where it concerns teachers from previously disadvantaged communities. Half of the teachers surveyed reported they felt ill prepared to teach the content of the mathematics curriculum. There appeared to be few teachers with significant experience, with a relatively small percentage having a university level qualification. Their lack of adequate preparation in terms of content knowledge in particular leaves these teachers feeling poorly prepared to teach their pupils. While numerous national efforts are underway to advance the status and teaching of mathematics in South Africa, initiatives to foster Continuous Professional Development (CPD) are largely driven by Higher Education Institutions offering accredited distance education courses, with in-service education and training efforts largely limited to workshops offered by the various Departments of Education (DOE).

However, the usefulness of workshops or event-delivery is debated by many authors (Guskey 1986; Clark 2002; Knight 2002). As Wiske, Sick & Wirsig (2001) summarizes, workshops are inclined to focus on general topics, are inattentive of teachers’ individual interests, are disconnected from specific classroom practices and are isolated from ongoing support. Some of the other pertinent limitations identified by Becher (1999) are costs (rural teachers, in particular, are geographically dispersed) and variability in the quality and level of CPD provision. Given the diversity of South Africa’s educational environments and the numerous echelons of educators, there is bound to be some level of disparity between provision and needs. These limitations are further enhanced in the absence of a clear CPD strategy for educators in South Africa (Mashile 2002).

Cluster meetings, where teachers gather in language groups and geographical proximities, are a new initiative that aims to overcome these shortcomings. The purpose of these meetings is to enhance ongoing faculty and course/curriculum development. There is evidence, however, that cluster meetings are not popular, possibly as a result of the greater demands it places on

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them and Subject Advisors (Venter 2003). More importantly, because of their geographical isolation, many teachers in rural areas will remain on the periphery of CPD opportunities like cluster meetings.

The sudden, rapid and dramatic advent of the World Wide Web (WWW) and its communication conduit, the Internet, with its multimedia capabilities, interactive tools and telecommunication facilities, seems full of potential as a catalyst for significant and sustained CPD of geographically dispersed mathematics teachers. Accordingly, in recent years there has been a significant and continual increase in research efforts aimed at exploring the role and contribution of the WWW to all levels of education. One such research route focuses on the use of online discussion forums in an attempt to create virtual communities of practice wherein CPD can occur.

While pressing questions remains as to how online activities support quality and success in online endeavours (King 2002), there is little doubt that Internet technologies are a dominating force, and as such, are bound to transform traditional CPD models.

2. PROBLEM IDENTIFICATION

Schagler and Fusco (2003) reports that in education reform and teacher training projects, much time was dedicated to create and support sustainable and scalable online communities of education professionals. They note that for the most part, those communities have been created in isolation from the existing local professional communities within which the teachers practice and that professional development should be treated as a socio-organizational system. They warn that there are socio-cultural preconditions that needs to be considered to prevent “us from putting the cart before the horse” when developing online education. Their research supports their viewpoint by arguing that a “virtual community” must evolve with a group, around their particular needs, and for purposes that they value as meaningful.

Smiley and Conyers (1991), in reconceptualising CPD for teachers, called for a paradigm shift from learning separately and learning through replication (static learning) to learning together and practicing reflection (interactive learning). As (Barnett 1998) notes, teachers are often isolated from one another and there is a need for them to engage in inquiry and reflection, a viewpoint supported by Clandinin and Connelly (1995) and Stein, Smith and Silver (1999). Reflection, communication with colleagues and the exchange of knowledge and ideas is thus the conceptual backbone of this paradigm shift. In supporting this viewpoint, the Norms and Standards for Educators (Republic of South Africa Government Gazette, 2000) state that reflective competence is one of three strands of competence required of all teachers.

All the above viewpoints are particularly suited to an on-line discussion forum environment. However, South Africa is a country defined by diverse socio-cultural communities. In general terms, the white population group is recognized as (previously) advantaged, while the black population group is recognized as (previously) disadvantaged. Schagler and Fusco’s (2003) warning thus acquires added significance in this context, and the first question that arises is what personal and situational tensions are influenced by these cultural communities, and how their actions are influenced by their setting. Human activity should be studied in their real-life situation (Marshall and Rossman 2006), and this study therefore adopted the qualitative research paradigm.
Since the current study was aimed at producing an understanding of the context of implementation of an IS and the process whereby the use and value thereof was influenced by the context, a revelatory, interpretive and descriptive perspective was adopted as philosophical base.

As research approach, we used both grounded theory (GT) and activity theory (AT). The motivation is that GT is useful for deconstructing the raw data and AT is useful in focusing both the deconstruction and the analysis of data.

Annels (2006) notes that different research approaches can be creatively and successfully used in one project if there has been adequate consideration of vital factors that determine if there is a good ‘fit’ of the approaches, not only with the research problems and questions, but also with each other, while maintaining the integrity of each approach.

 Whereas GT is a well-known and applied research approach, AT is a relative new concept and we therefore give some additional background on the underpinning theory of the approach.

### 3.1.1 Activity Theory

AT is particularly suited as a theoretical framework to follow when context is acknowledged. This study was underpinned by the philosophy that “participation in social organizations (e.g. families, communities, institutions or other informal collectives) provides for a complex set of interactions from which we cannot extricate ourselves; we are simultaneously affected by our social environments while, at the same time, we participate in their creation” (Little, McAllistair and Priber, 1997).

Leontiev (1981) states that attempts to correlate context and participants as interactants in communicative events (such as that which the ODEM offers) suggests the possibility of interpreting their interrelationship by applying the tri-stratal analysis of social activity. Figure 1.1 presents this tri-stratal framework.

![Figure 1.1 The tri-stratal framework of Activity Theory](image)

The three primary components of an Activity System (AS) are the subject, the object of the activity and the community in which they occur. For example, the subject is a mathematics teacher, the object is to participate in the ODEM and to build an online community, and the community is advantaged or disadvantaged. Each activity the teacher performs, for example participating in the ODEM, is analyzed as part of the collective and with a social-cultural context of the individual and the collective. A shared understanding of the character and history of the subject, the object which the individual is trying to reach, the characteristics of the community and the tools available to the subject is required if sense is to be made. Supporting components on the apexes of the triangle are the rules, the tools used, and the division of labour (roles). Here the rules were reflection and sharing with colleagues, the tools were an Internet ready computer with access provided from home, and the division of labour was for teachers to post and respond to posts, and the goal was CPD. In the process of the object changing, all the other components adopt new perspectives, and a new Activity System is born. For example, if a computer experiences a hardware problem, the goal of the AS changes, as does the rules and the division of labour.

One of Engeström’s (1987) original motivations for developing this model was to allow researchers to identify the inner contradictions that impose tensions on participants’ settings and help them change the nature of an activity to overcome these tensions. A tension essentially brings instability to an Activity System. The identification of tensions therefore provides an indication of the stability of the Activity System. If there are no tensions, there are no contradictions and the nature of an activity does not have to change in order to overcome the contradictions, or to solve the tension for that matter.

### 3.2 Subjects

Ten disadvantaged teachers and ten advantaged and motivated mathematics teachers who regularly participate in Cluster meetings were identified by the Subject Advisor for the Gauteng North Area, and were invited to participate in the study. A total of 9 disadvantaged teachers (4 female and 3 male) and 7 advanced teachers (6 female and 1 male) volunteered and were provided with home Internet-ready computers and 10 hours Internet access per month for a period of 4 and 5 months respectively in 2006. The advantaged group participated an extra month since their period included a traditional holiday month.

Both groups attended workshops before implementation where they were introduced to and trained in using the ODEM, and sensitized to reflective practices. The disadvantaged group was, with the exception of one teacher, PC-illiterate, while the advantaged group, with one exception, was PC-literate. All teachers taught at least grade 7 and taught in schools mirroring their level of advantageousness.

### 3.3 Data collection and analysis

Activity Theory techniques utilized led exclusively in the discovery of Activity Systems that aimed to compartmentalize data decomposition and forming sensible units for analysis. Grounded Theory techniques employed focused on the decomposition of data collected from semi-structured interviews on completion of the project, server logs, our own and research diaries kept throughout the study, the posts made to the ODEM and a focus questionnaire, thereby providing multiple perspectives and ensuring triangulation of data (Glaser and Strauss 1967; Orlikowski 1993; Pandit 1996).

The analysis and reporting of data was pursued in the following order.

As a first step the interviews with the teachers, their research- and our own research diaries were open-coded in order to indentify emerging concepts. These concepts were then grouped together in categories of best-fit. The categories that emerged were then used to identify sub-cases, or Activity Systems.

Secondly, each Activity System was then decomposed within its framework of subjects, rules, community, division of labour and the objects and goals. An attempt was made to interpret the collected data by identifying and describing the Activity System’s components and possible tensions that existed in and between components. Decomposition was a revelatory process – with each additional category decomposed, more insight was gained into previously decomposed categories. These insights
forced us to regularly revisit the raw data in order to confirm and/or expand the growing “picture” that emerged. Thus, rather than following a step-wise process, we adopted a cyclic process of open-coding, decomposition and axial coding. That is, as more and more categories were decomposed, more tensions surfaced which either explained or exaggerated previous tensions.

Thirdly, connections between categories and its concepts were integrated as part of the interpretation phase – bring meaning and coherence to the categories, developing linkages between tensions identified and making sense of the interview and journal data and the posts made to the ODEM. In a GT approach this process is known as axial coding. In this endeavour lied additional purposes of confirming existing or indentifying other tensions that may resolve or exaggerate the tensions already identified. Note that axial coding was not a third step as such, but attempted throughout the analysis as tensions emerged.

4. PERSPECTIVES OF THE TWO GROUPS

In the following two sections, section 4.1 and 4.2 we report on the results found from the perspective of the disadvantaged group and the advantaged group.

4.1 Disadvantaged group

Two Activity Systems were identified for the disadvantaged group: DAS1: Connecting to the ODEM, and DAS2: Using the ODEM (DAS1 refers to Disadvantaged Activity System 1). Several tensions were associated with these Activity Systems. The table shows DAS1 tensions to be situational, non-ODEM-related and limited to the tools and division of labour components, while DAS2 tensions were spread over AS components. The immediate impression gained is that disadvantaged teachers experienced a variety of tensions from various sources.

T1|DAS1: Creating Internet Accounts played a significant role in disrupting DAS1: Connecting to the ODEM, and resulted in the project being delayed for several months. This tension had several facets: the general unavailability of telephone lines for Internet connections and resultant difficulties in contacting teachers to install telephone lines, the role of Telkom as service provider and accounts creator, and the financial limitations of teachers. In essence, this tension existed because the community is disadvantaged. For disadvantaged teachers “getting online” from home is an arduous process that requires know-how, time, effort, support and cost.

T2|DAS1: Connection Problems, similar to T1|DAS1: Creating Internet Accounts exaggerated T3|DAS1: Lack of Suitable Support Structures. The focus here is not so much on the connection problems that were experienced since connection problems occur in all communities, but rather on the difficulty in providing support when connection problems did arise. These connection problems impacted on both DAS1 and DAS2. If T3|DAS1: Lack of Suitable Support Structures can be resolved, T2|DAS1: Connection Problems will cause less imbalances in both Activity Systems, allowing teachers to focus on the goals of the Activity System.

T3|DAS1: Lack of Suitable Support Structures was exaggerated when teachers did not receive adequate support from the primary support agent which was Telkom. Here Telkom was an outside influence that became internal to the activity, and contributed to an imbalance in DAS1. When teachers experienced connection problems, they phoned Telkom for support as directed. In some instances the inability of the Telkom Call Center agents to provide support to PC-illiterate teachers forced us to adopt an unexpected and secondary support role. For example, when hardware problems surfaced, teachers had to make use of public transport to visit us at home after hours - which is difficult if one has to haul a PC-tower along in overcrowded minibuses. The absence of PC-companies in Townships exaggerates this tension.

The tensions of DAS1: Connecting to the ODEM thus all contributed towards the object of connecting to the Internet not being attained and the goal of participation in the ODEM not being realized for a long period of time. When T1|DAS1: Creating Internet Accounts was eventually resolved and teachers were in a position to connect to the ODEM, T2|DAS1: Connection Problems resurfaced for some teachers throughout the project.

The majority of DAS2 tensions were associated with the rules and subjects (seven of the twelve tensions identified were associated with these two components, while the other five tensions identified were associated with three components). While it is tempting to conclude that the rules of DAS2 did not suit the subjects, such a conclusion would be premature without a review of each tension.

T1|DAS2: What to Post is a complex tension which was not resolved within the time frame of the study. Data from attempts and nature of posts showed most teachers to have previewed their posts considerably more than what was eventually posted and that they were more inclined to respond to as opposed to starting a new thread. No posts contained any expressions, and in the absence of expressions (which requires a steeper learning curve than text-only posts) the excess previews generated implies that teachers were continually assessing the perceived value of their contributions. Several other tensions, notably T3|DAS2: Lack of Fervour, T4|DAS2: Lack of Reflective Practices and T12|DAS2: Leader Required has the capacity to exaggerate this tension. Conversely, if tensions such as T9|DAS2: Training Required, T10|DAS2: Lack of Motivation and T12|DAS2: Subject Advisor Required can be resolved, they may (individually or collectively) resolve this tension. For example, having a knowledgeable Subject Advisor (in terms of understanding teacher needs) participating in the ODEM may well coerce teachers into regular contributions. The permutations between these tensions are endless. What endures is that T1|DAS2: What to Post exaggerated T8|DAS2: Quality of Participation.

T2|DAS2: Irregular Contributions was identified when it became apparent that, with the exception of two teachers, contributions were minimal even when most of DAS1’s tensions were resolved. All of DAS2’s tensions could have, collectively or in small parts, contributed to and/or exaggerated this tension. How it did would have depended on individual circumstances. For example, T8|DAS2: Quality of Participation was exaggerated for two teachers when other teachers’ responses to their posts were, according to them, unsatisfactory. For these other teachers, T1|DAS2: What to Post played an important role in T2|DAS2: Irregular Contributions being exaggerated. Likewise T7|DAS2: School/Township Related Issues may have played a significant collective or individual role in exaggerating T2|DAS2: Irregular Contributions. As with T12|DAS2 in the previous paragraph, if some or all of the tensions are resolved, they may contribute towards resolving this tension.

T3|DAS2: Lack of Fervour surfaced as a tension given the one-dimensionality of questions and responses. This tension could have had a potential snowballing effect on T8|DAS2:
Quality of Participation where feeble questions spawned feeble replies. As with T2\textsubscript{DAS2}, all the tensions identified from DAS\textsubscript{2} could potentially have impacted on this particular tension, either in exaggerating or resolving it.

T4\textsubscript{DAS2}: Lack of Reflective Practices was identified when the nature of the posts were investigated. A comparatively low percentage of posts contained evidence of reflective practices. In addition, teachers were somewhat divided on the value of the ODEM as a tool for reflective practices, preferring a content-driven approach. Some of the other tensions may have contributed to the lack of reflective practices. For example, not being able to resolve a content issue or a disciplinary problem may inhibit reflective practices by changing a teacher’s focus. Nonetheless, should one value reflection as a powerful tool in the CPD of teachers, the data shows the ODEM to not have nurtured reflective practices, although their efforts at reflective practices are noticed.

Table 1.1 Disadvantaged Tensions of DAS\textsubscript{1}: Connecting to the ODEM and DAS\textsubscript{2}: Using the ODEM

<table>
<thead>
<tr>
<th>AS components</th>
<th>ODEM-related tensions</th>
<th>Non-ODEM-related tensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Personal</td>
<td>Shared</td>
</tr>
<tr>
<td>Rules</td>
<td>T\textsubscript{1}DAS\textsubscript{2}: What to Post</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{2}DAS\textsubscript{2}: Irregular Contributions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{3}DAS\textsubscript{2}: Quality of Participation</td>
<td></td>
</tr>
<tr>
<td>Subjects</td>
<td>T\textsubscript{3}DAS\textsubscript{2}: Lack of Fervour</td>
<td>T\textsubscript{5}DAS\textsubscript{2}: Financial Factors</td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{4}DAS\textsubscript{2}: Lack of Reflective Practices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{10}DAS\textsubscript{2}: Lack of Motivation</td>
<td></td>
</tr>
<tr>
<td>Community</td>
<td>T\textsubscript{9}DAS\textsubscript{2}: Training Required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{11}DAS\textsubscript{2}: Point of Access</td>
<td>T\textsubscript{1}DAS\textsubscript{1}: Creating Internet Accounts</td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{2}DAS\textsubscript{1}: Connection Problems</td>
<td>T\textsubscript{3}DAS\textsubscript{1}: Connection Problems</td>
</tr>
<tr>
<td>Tools</td>
<td>T\textsubscript{12}DAS\textsubscript{2}: Leader Required</td>
<td>T\textsubscript{3}DAS\textsubscript{1}: Lack of Suitable Support Structures</td>
</tr>
<tr>
<td>Division of labour</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key example: T\textsubscript{1}DAS\textsubscript{2}: What to Post refers to Tension 1 ‘What to post’ identified from Disadvantaged Activity System 2.

T\textsubscript{5}DAS\textsubscript{2}: Financial Factors was identified as a tension because it impacted on both connecting to and using the ODEM. This tension was specific to many teachers not having an existing telephone line and to two teachers experiencing financial difficulties during the project. Not having telephone lines had a major impact on DAS\textsubscript{1} and delayed the project substantially. Experiencing financial problems should not have affected the two teachers’ participation since participation did not cost them any money. However, the one teacher had his line disconnected while the other could not use the funds we paid into his account due to a debit balance. Although arbitrary

the exception of one teacher, none of the teachers continued their Internet accounts on completion of the study, which raises questions on the sustainability of pursuing online CPD in disadvantaged communities, especially if one considers that very few of the teachers reported having access to school computer laboratories, with half preferring access from school even if access was available at home. T\textsubscript{5}DAS\textsubscript{2}: Financial Factors also interacts with T\textsubscript{3}DAS\textsubscript{1}: Lack of Suitable Support Structures in that there are costs involved in seeking and providing support. More often than not, we had to carry the costs of expensive cell phone calls to teachers in order to resolve their problems. When hardware problems (mainly related to PC-modems) surfaced, teachers also had to pay for public transport in order to bring their PC-towers to us after hours.

T\textsubscript{6}DAS\textsubscript{2}: A Busy Life is generic to a demanding family- and professional life, and impacted mainly on the time teachers had available to spent on the ODEM. Providing a specific
packaged-Internet time period that they could connect to the ODEM had advantages in cost, but placed more demand on teachers thereby exaggerating this tension. There against, if the ODEM can replace cluster meetings, which demand a lot of travelling and thus time, time is saved. It could also be argued that by using the PC for administrative tasks (like some teachers did), more time is saved, although this would depend on their level of PC-literacy. This tension may well have contributed to or exaggerated T2|DAS2: Lack of Fervour, T8|DAS2: Quality of Participation, T11|DAS2: Point of Access and T10|DAS2: Lack of Motivation.

T7|DAS2: School/Township Related Issues highlighted community-specific problems the disadvantaged teachers experienced. Disciplinary problems in school were highlighted as a major factor that affects the morale of teachers. High levels of crime in Townships resulted in upgraded computer laboratories being burgled overnight. One teacher was so badly affected by a criminal incident where guns were drawn that it left him unable to contribute to the ODEM for several weeks. The fact that teachers saw value in the ODEM as a communication line to a Subject Advisor indicates the need that these teachers have for support in a school system that some teachers perceived as “being in a mess”. It must be extremely challenging for teachers to commit to CPD opportunities when, seemingly, life is not mundane. This tension has the potential to contribute towards, or exaggerate T10|DAS2: Lack of Motivation.

T8|DAS2: Quality of Participation was identified when the value and depth of the interactions that took place in the ODEM were reviewed. Already referred to, this tension was specifically exaggerated by T1|DAS2: What to Post and T3|DAS2: Lack of Fervour. But other tensions from DAS2 may also have contributed to this tension in small parts. In fact, the intensity of this tension can be viewed as an indicator of the stability of DAS2. More importantly, the strength of this tension represents the final conclusion one can make on the value of the ODEM in the CPD of disadvantaged teachers. This tension arose because of other tensions, implying that those tensions must be resolved first before quality of participation will improve.

T9|DAS2: Training Required surfaced when it became apparent that teachers overestimated their level of PC-literacy. Despite the ease of use of the ODEM, two supporting workshops and a requirement that participants must be computer-literate, most teachers felt they required more training. Some doubt surfaced as to the worth of their statements on training since these calls for more training may well have been used as a justification for poor participation rates. After all, if a teacher can make one post, then there is no reason they cannot post more – except if there are other tensions at play. The impression gained was that teachers required more training in how to use the ODEM more effectively than training in PC-literacy skills. This does not imply providing exact and/or regulatory pointers on what to post - it requires that teachers are nurtured, encouraged and reassured. A sympathetic Subject Advisor who can gently train (or elicit) reflective techniques may well resolve this tension.

T10|DAS2: Lack of Motivation refers partly to evidence that teachers may have enlisted in the study for the wrong reasons (obtaining a free computer and Internet access) and that this discord may have, contrary to expectations, impacted on their motivation to participate on a regular basis. While this tension potentially contributed to T3|DAS2: Lack of Fervour, T1|DAS2: What to Post and T2|DAS2: Irregular Contributions, it may equally be the product of other tensions or processes. For example, if a teacher does not receive useful responses to his posts, he may become demotivated.

T11|DAS2: Point of Access was a personal tension in some instances (one teacher accessed the ODEM from her parents home which required travelling to and from her own home while another was in the process of divorce) and situational in others (the lack of laboratories forced home access). T6|DAS2: A Busy Life could be resolved to some extent if teachers could access the ODEM when and where it suited them. However, we have already highlighted the fact that neither access from school laboratories nor home is presently viable for most teachers. This tension may have contributed to T2|DAS2: Irregular Contributions.

T2|DAS2: Leader Required was confirmed as a tension when it became apparent that teachers have a need for leadership within the ODEM and outside of the ODEM, with the ODEM serving as a convenient channel of communication. An obvious leader that could fulfil both roles would be the Subject Advisor. This advisor will need to stimulate discussion, to nurture, encourage and reassure teachers within the ODEM and provide support on issues outside the ODEM (e.g. disciplinary problems) which inhibit optimal participation in the ODEM. Thus she finds herself in a primary position to resolve most of the tensions of this group.

4.2 Advantaged group

Only one Activity System, AAS1: Using the ODEM, was identified for the advantaged group. Consider Table 1.2 which groups the tensions identified according to Activity System components, whether they were ODEM- or non-ODEM-related, and whether they were personal, situational or shared.

Table 1.2 shows the advantaged group to have experienced far fewer tensions than the disadvantaged group, with no tensions related to their community and only two tensions existing outside the rules and subjects.

T1|AAS1: Starting Threads was identified when it became apparent that advantaged teachers preferred to respond to existing threads rather than start threads. This tension threatened the sustainability of the ODEM and contributed towards exaggerating T5|AAS1: Quality of participation. One plausible reason for this tension could be that teachers preferred to adopt a leader role rather than risking an exposure of their (perceived) shortcomings. Teachers also had several suggestions on how the ODEM could be employed to add value to their practice, yet few were prepared to initiate discussions along these suggestions. In some instances, a snowball effect materialized, where threads that were perceived as meaningless generated even more meaningless responses, thereby exaggerating T5|AAS1: Quality of participation.

T2|AAS1: Lack of Reflective Practices was identified when it was discovered that despite teachers showing evidence of being accomplished reflective practitioners, a low percentage of posts were reflective in nature. Evidence from the nature of posts suggested that teachers have more practical needs they want fulfilled. In particular, and as the data analysis progressed, it became more and more apparent that teachers experience immense frustrations in their practice and that they have a far greater need for the ODEM to serve as a direct channel of communication to a Subject Advisor who they perceive as being distant and ignorant to their problems.

T3|AAS1: Slow Connections was a source of frustrations for many teachers. The constant struggle teachers experienced making connections to the Internet in order to visit the ODEM exaggerated both T4|AAS1: A Busy Life and T5|AAS1: Quality of participation. The relatively low number of posts highlights
the effect this tension may have had on the stability of the Activity System.

T4|AAS1: A Busy Life was the most pervasive tension impacting on the Activity System. Not having enough time impacted on the intention to contribute meaningful threads, or contributing to and/or exaggerating T2|AAS1: Starting Threads, which in turn contributed to and/or exaggerated T5|AAS1: Quality of participation. Some teachers connected on own cost at times outside the allotted Internet package time, indicating how powerful this tension was.

T5|AAS1: Quality of participation has already been linked to other tensions. The primary source of this tension may be that the needs of the teachers were not addressed. Two teachers suggested that they merely “went through the motions” in an effort to comply with the rules of the Activity System. This is not to suggest that teachers did not find value in the ODEM – most did – but merely that the rules of the current Activity System were not congruent to their immediate needs.

### Table 1.2 Tensions of AAS1: Using the ODEM

<table>
<thead>
<tr>
<th>AS components</th>
<th>ODEM-related tensions</th>
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<td>Rules</td>
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<tr>
<td>Subjects</td>
<td>T2</td>
<td>AAS1: Lack of Reflective Practices</td>
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<tr>
<td>Community</td>
<td></td>
<td></td>
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<tr>
<td>Tools</td>
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<tr>
<td>Division of labour</td>
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</table>

Key example: T4|AAS1: Starting Threads refers to Tension 1 'Starting Threads' identified from Advantaged Activity System.

T6|AAS1: Subject Advisor required was identified when teachers’ real needs became apparent. These needs were mostly related to issues surrounding departmental policies and the need for Subject Advisors to act as a soundboard to their frustrations. It is reasonable to propose that if the rules of the Activity System were changed to “communicate with the Subject Advisor when needed and view Subject Advisor communications”, then all the tensions, except slow connections and a lack of reflective practices, will be resolved.

T7|AAS1: Substance required is closely related to T5|AAS1: Quality of participation in that one tension feeds of the other. If there is no quality of participation, there can be no substance, and vice-versa. This supports the notion that teachers’ real needs were not addressed by the current rules of the Activity System.

### 4.3 Core tensions

A dynamic interaction between all the existing tensions, individually and collectively, was evident. As these tensions become internal to the identified Activity Systems, some tensions had the ability to exaggerate other tensions, while other tensions, if resolved, has the potential to resolve other tensions. A question that remains is what the core tension(s) of each group were?

In the previous sections we adopted a vertical perspective in discussing the results. The majority of tensions (12 of the 22 tensions identified in DAS1, DAS2 and AAS1) were found along the Personal|Subjects and Personal|Rules intersections. This finding indicates that the rules of the current Activity Systems (reflecting on and sharing their practice) did not fit the current subjects, resulting in several personal and situational, ODEM- and non-ODEM-related tensions surfacing that impacted on the object of participation and community building.

However, from a horizontal perspective, it becomes evident that tensions to the right in Tables 1 and 2 exaggerate tensions to the left. Consider the disadvantaged ODEM-related tensions presented in Table 1. If T12|DAS2: Leader Required is resolved through an active leader who provides training, guidance, encouragement and support via the ODEM, then T1|DAS2: What to Post, T2|DAS2: Irregular Contributions and T8|DAS2: Quality of Participation will be largely resolved. Similarly, on the non-ODEM side of the table, if all schools have safe and functioning computer laboratories from where teachers can access the ODEM, T5|DAS2: Financial Factors would be less pervasive, as would T6|DAS2: A Busy Life since teachers can access the ODEM in their free periods or when it suits them. T11|DAS2: Point of Access is also largely resolved since teachers will have reliable access.

It thus appears if situational tensions form the core tensions of the disadvantaged group, that is, T12|DAS2: Leader Required and T7|DAS2: School/Township Related Issues. A similar approach to Table 2 shows T6|AAS1: Subject Advisor required being the core tension for the advantaged group.

That these are the core tensions confirms some of the findings. That is, the exact role the Subject Advisor will play within each group is very different because of the variety of
tensions - the main notable variation being that the disadvantaged group requires macro leadership to solve their diverse tensions within and outside the ODEM, whereas the advantaged group merely requires the participation of a Subject Advisor - most notably as a soundboard for their frustrations experienced outside the ODEM.

5. CONTRIBUTION

Having developed a mathematics friendly forum environment for mathematics, we investigated and identified several personal and situational tensions that impacted on the use thereof as a reflective tool for the CPD of disadvantaged and advantaged teachers.

A review of the tensions indentified has led us to the following preliminary contributions:

- Participation by mathematics teachers in an online forum in pursuit of the CPD is influenced by forum- and non-forum-related tensions, the sources thereof either personal or situational. Situational tensions result in many of the personal tensions found. The impact of these tensions has the ability to destabilize an online forum and prevent the goal of CPD from being reached.
- Disadvantaged teachers generally face more tensions than advantaged teachers. Since these tensions have different sources and impact at different levels, the rules, the object and the goal of the forum should be specific to communities in acknowledgement of the importance of context.
- Forum tensions are closely associated with the real needs of teachers. If these needs are not resolved, tensions result.
- A Subject Advisor is best positioned to fulfill these forum needs by selecting an appropriate online CPD strategy given the tensions that exists.
- Whereas the ODEM can be a useful tool, a mathematics-friendly forum environment is not a current need.

6. CONCLUSION

The objectives of this research were firstly to develop an inexpensive and undemanding web-based Online Discussion Environment for Mathematics (ODEM). Such an environment was successfully developed to explore the second objective, which was to separately provide the ODEM to two groups of advantaged and disadvantaged mathematics teachers in order to discover the personal and situational tensions that impacted on the use of the ODEM as a reflective tool in pursuit of CPD.

An in-depth case study research was done where teachers from both the disadvantaged and advantaged groups were monitored and interviewed on the adoption and use of the ODEM system. The tensions found in the report back period were analysed and the researchers found that there are several tensions that prohibited the users from using the environment, not necessarily related to the environment itself.

For further research, the study should be repeated with larger groups but leadership should be originated from within the educational system itself to motivate participation.

This research gives once again emphasize that financial support for any new innovation are not necessarily enough motivation, but that leaders will have to be innovative in establishing new technologies.

7. ACKNOWLEDGMENTS

Our thanks to the Shuttleworth Foundation, The University of South Africa and the National Research Foundation for the grants received to purchase computers and provide Internet access for teachers.

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ABSTRACT
Communication forms the basis for personal relationships but technology has changed the way people communicate. This research investigates the impact that computer-mediated communication (CMC) has had on interpersonal relationships using a combination of technology characteristics and behavioural outcomes. These factors are explored by means of a qualitative study using interview and discussion group data from student users of email, mobile phone, Instant Messaging (IM) and Internet Relay Chat (IRC). This study provides a first-cut model that identifies some of these key characteristics and behavioural outcomes of CMC and their impacts on interpersonal relationships among South Africans.

CATEGORIES AND SUBJECT DESCRIPTORS
K.4.3 [Computers and Society]: Organisational Impacts – Computer-supported collaborative work.

GENERAL TERMS
Management, Measurement, Human Factors.

KEYWORDS
Computer-mediated communication, interpersonal relations, impact model, behavioural outcomes.

1. PROBLEM STATEMENT, OBJECTIVES AND RESEARCH QUESTIONS
This research addresses how social interactions, or more specifically interpersonal relationships, are affected by changing communication technologies. Rheingold [1] describes how CMC is used to conduct relationships as follows: “It is all about people communicating with other people, in any way they can and for many purposes: exchange pleasantries and argue, engage in intellectual discourse, conduct commerce, exchange knowledge, share emotional support, make plans, brainstorm, gossip, feud, fall in love, find friends and lose them, play games, flirt, create a little high art and a lot of idle talk.” [p. 3]

This study investigates communications conducted via interactive, or synchronous, CMC media only. This is motivated by the fact that communication in interpersonal relationships is typically interactive. CMC media usage observed in this research will therefore include only email, instant messaging (IM), internet relay chat (IRC), mobile phone voice calling, text messaging and multimedia messaging (MMS). In addition, only non-work related interpersonal CMC are of interest as the research aims to gain insight into how the more intimate and private aspects of human relationships have been affected by CMC.

Interpersonal communication is considered to be the most important use of the internet [2]. In addition, mobile phone subscribers exceed fixed lined subscriber’s world-wide [3]. As a result, CMC is clearly pervasive in society and the transition from the traditional to the electronic is a challenge to communication research [4].

This study provides a first-cut model which identifies some of the most important characteristics and behavioural outcomes of CMC as well as their impacts on interpersonal relationships among South Africans.

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2. LITERATURE SURVEY

2.1 Computer-Mediated Communication (CMC)

CMC as defined by [5] is any communication that is mediated by a computer which occurs on an interpersonal or group level but excludes mass communication. In the context of the communication models described previously, the ‘communication channel’ or medium is provided by Internet- or mobile phone-based communication technologies, for example IM, text messaging or email. In addition both the message ‘source’ and ‘destination’, otherwise known as ‘participants’, are human.

The features of communication, as represented by the models of communication discussed previously, can be applied to certain Internet- and mobile phone-based CMC media as depicted in Table 1.

Table 1. Features of Internet- and mobile phone-based CMC media

<table>
<thead>
<tr>
<th>Feature</th>
<th>Internet-based</th>
<th>Mobile phone-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple recipients by default</td>
<td>Y</td>
<td>N, N, N</td>
</tr>
<tr>
<td>Mainly text-based messages</td>
<td>Y, Y</td>
<td>Y, N, N</td>
</tr>
<tr>
<td>Message length limited</td>
<td>N, N, N</td>
<td>Y, Y, N</td>
</tr>
<tr>
<td>Synchronicity/Interactivity</td>
<td>Low, High</td>
<td>High, Some, Low, High</td>
</tr>
<tr>
<td>Delays between messages</td>
<td>Yes, Slight</td>
<td>Slight, Slight, None</td>
</tr>
</tbody>
</table>

Although CMC may be seen to complement traditional communication methods, Jarvenpaa and Lang [6] state that CMC facilitated by mobile technologies might influence the effectiveness of other kinds of communication adversely. This is supported by Srivastava [3] who noted that teenagers who send text messages excessively may impede their ability to interact on a voice or face-to-face basis.

In contrast to face-to-face communication, the absence of meaningful, nonverbal cues in CMC may impede its effectiveness. Examples of such cues include hand gestures, facial expressions, eye movements and tone of voice each of which transcends the mere spoken, written or typed word [7]. This absence of nonverbal cues from CMC prompted a significant portion of earlier CMC studies which emphasised the differences between CMC and face-to-face communication [8]. CMC has evolved its own way to convey emotion and tone that relies on cues such as ‘smilies’ and other ‘emoticons’ which have themselves become objects of message meaning negotiation [9]. Other cues in text-based CMC include language usage, style, speed of writing, punctuation usage and timing [9].

2.2 The Conceptual Model for CMC and Interpersonal Relationships

A tentative model was derived using various constructs and factors found in the literature. The key identified constructs and the relationships between these constructs are depicted in Figure 1.

Figure 1. Hypothesized impacts of CMC characteristics and outcomes on interpersonal relationships.

In the proposed model, constructs are classified as being either a ‘Characteristic’ of CMC, labelled C1 through C3, or a behavioural ‘Outcome’ of CMC, labelled O1 through O6. In addition, relationships between constructs are labelled R1 through R7 and can be either positive or negative. Impacts of constructs on interpersonal relationships are labelled I1 through I9. Note that our concept of behavioural outcomes differs from the types of outcomes investigated by Spitzberg [10] who investigated outcomes for the purpose of determining CMC competence. Table 2 summaries the constructs and indicates key literature that provides evidence of the existence and nature of each construct.

Table 2. Brief description of constructs with related literature

<table>
<thead>
<tr>
<th>Construct</th>
<th>Brief Description</th>
<th>Key Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always On [C1]</td>
<td>CMC characteristic that affords “permanent connectivity”.</td>
<td>[3,6,11]</td>
</tr>
<tr>
<td>Anonymity [C2]</td>
<td>CMC characteristic that allows true identity of the people communicating with each other to remain hidden.</td>
<td>[4, 9, 12, 13]</td>
</tr>
<tr>
<td>Placelessness [C3]</td>
<td>CMC characteristic that allows people to communicate or “meet” in a virtual environment, independent of physical location.</td>
<td>[3, 13, 14]</td>
</tr>
<tr>
<td>Physical Isolation [O1]</td>
<td>Outcome of CMC as communicating no longer requires physical contact.</td>
<td>[3, 11, 12, 14, 15, 16, 17]</td>
</tr>
<tr>
<td>Invasion of Privacy [O2]</td>
<td>Outcome of CMC as possibility for messages to be intercepted is increased. Also incorporates possible invasive nature of CMC and reduced “private time”.</td>
<td>[3, 6]</td>
</tr>
<tr>
<td>Etiquette [O3]</td>
<td>Outcome of CMC that involves changing communication manners such as inappropriately timed communications and inappropriate communication style.</td>
<td>[3, 6, 7, 11, 12]</td>
</tr>
</tbody>
</table>
3. RESEARCH METHODOLOGY

3.1 Study Design

The timeframe of this study was cross-sectional. A qualitative research methodology was chosen because the study deals with quite complex social phenomena. A qualitative research method, encompassing both unstructured interviews and unstructured discussion group sessions, was more suited as the study is an exploratory analysis of people and their behaviour. In addition, this research aims to test the relationships between the various constructs in the proposed model. Since most of these constructs and relationships are not clearly measurable and some indeed are largely undefined, a qualitative methodology was suited towards this type of situation. Finally, it was hoped that an exploratory qualitative study might identify other themes or relationships that have been left out of the proposed model. This would not be possible with a structured quantitative questionnaire as newly uncovered themes could not be pursued through modifying the research angle as needed.

3.2 Data Collection

Two data collection methods were used namely interviews and discussion groups. Six one-on-one interviews and two pair-based interviews were conducted. The interview participants ranged from age 18 to 72 and were both male and female. In addition, two discussion group sessions were held. The first had eight female participants ranging in age from 19 to 45, the second had seven participants of similar demographics. A prompt sheet was used and partly transcribed into digital text format for further analysis. It was found that generally nothing new emerged from interview P8 and discussion group DG2 and this is when data collection activities ceased.

3.3 Data Analysis and Discussions

The transcribed interviews and discussion group data were combined under the ten constructs of the proposed model. Relevant direct quotes of the participants’ comments were highlighted in yellow and researchers’ comments highlighted in blue. Mind mapping was the main technique used to organise themes under each construct. This was seen as the most efficient way of exploring and documenting themes amongst the heavily interrelated data. The presentation below discusses the inferences about the themes and the nature of their relationship to interpersonal relationship as the dependent construct. First the three characteristics are discussed and then the identified outcomes (i.e. the order as per table 2) except that anonymity and risk-free experimentation were so closely associated by all respondents that they are discussed together.

3.3.1 Always On (C1)

A very evident and often much deliberated theme amongst participants was that CMC has allowed people to stay in contact at all times. This is mainly due to the mobility afforded by mobile phones in particular. While CMC made communication easier, it was also noted that a lot of unnecessary information. Some participants described feeling overwhelmed and often frustrated as they have to ‘wade’ through layers of trivial communications in order to get through to the more important and meaningful messages. As one frustrated participant (P3) commented: “It’s trivial information coming from people making trivial arrangements... did you need to make that call? No.”

A concern expressed by parents was that their children were becoming addicted to their mobiles and not able to function normally without them. An exasperated parent commented on how their children spent their entire holiday text messaging. She quipped: “Next time we go on holiday we’re just going to lock the two of you in a room [with your phones].” (DG1)

While this dependence on being permanently connected was prevalent in adults as well, the nature of the dependence was different. Adults rely heavily on their mobiles to keep in contact with colleagues or clients, while for young adults and children the mobile was their primary means of sustaining their social lives.

Because a channel of communication is open at all times, people are taking active steps to disconnect themselves. This may be as simple as the common practice of having two separate mobile phones or email addresses, one for work, and the other for private use. Other methods employed by participants to disconnect when the communication is not desired include switching a mobile to silent and ignoring calls. Interestingly, very few of the participants would switch off their phones, saying that they still wanted contact with the outside world, but needed to control that contact: “It’s nice to be able to be contacted any time, any place, but it’s also nice to have control over that.” (P4)

This ability to filter incoming messages and choosing whether to respond or not has become common in all forms of CMC. Participants described using filters for email, setting IM profiles to ‘busy’ or simply not responding to text messages as means of filtering communications: “When you get this hub of communication thrust into your life, in your bedroom...24/7, yes, you need the ability to filter, because it never used to be like that.” (P4)

There might be some correlation between age and the willingness to disconnect. Most adults were more than willing to switch off their mobile given the right circumstances (e.g. late at night or while on holiday). Younger participants where notably against the idea of disconnecting, though in one case it was suggested that once they started working they may be more willing to do so. If the ‘disconnection’ is forced upon an individual, such as a loss of signal, or the inability to access a computer, it could lead to a form of social exclusion. This can be attributed to more effort being needed to contact that person, and if they are not close friends they could be left out all
together. Two participants stated that they did not talk to friends who were not on IM as much as they did to those who were.

3.3.2 Anonymity (C2) and Risk-free Experimentation (O4)

‘Risk-free Experimentation’ as a construct was heavily dependant on the characteristic of ‘Anonymity’ and was never raised outside the context of anonymous communications. Because of this close association, the two constructs are discussed together.

Anonymity is facilitated by all non-face-to-face communication. However, in CMC it is most notably prevalent in IRC interactions and through mobile phone calls in which the caller’s identity is withheld otherwise known as ‘private number’ calls. Most of the participants said that they would treat such communications with some weariness. Private numbers were described by one participant as “The worst number I take” (P2) as she did not know who was calling, but had to answer because it was likely to be a call from work. Other participants said that they treat private numbers with some caution as they could be “cold calls” from telemarketing companies which were seen as a nuisance. While anonymity on mobile phones is seen as a nuisance, it is much less prevalent than in IRC.

Given that anonymity is a key feature of chatting over IRC it has shaped the reasons for communicating over IRC and the people who use it. It is very difficult and often impossible to ascertain the real identity of the person you are interacting with on IRC. Most of the respondents that had used IRC said that they chose to use it because they were either lonely, and it was a convenient means of contacting other people, or that they wished to experiment with social dynamics in a consequence-free environment.

Talking from her own experience, one participant explained how she had felt lonely at college and did not want to get involved in the local social scene. She says IRC was a good means of passing the time when she had nothing better to do, because it was a quick and convenient way of meeting people, but the conversations and interactions were meaningless. The concept that anonymity detracts from the meaning of a conversation was a common theme amongst the participants.

Since the conversations hold little value to the participants, IRC discussions tend to be light-hearted. This casualness extends to the outlook of those using IRC. Since there are few consequences to what is said online it can lead to some mischievous behaviour. As one participant explained: “It’s quite a cool place to be bad in because you’re not responsible. Providing you aren’t stupid, you can be naughty and have no repercussions.” (P5). Other participants agreed with this idea, and added that “as long as no one gets hurt, it’s alright” (P8).

Due to the anonymity afforded by IRC, people will often act in devious ways that might be overtly rude, crude and generally unpleasant. IRC chatrooms have a reputation of being havens for paedophiles and other sexual miscreants as discussed in the next section.

Many participants are ex-IRC users and have moved on to more personal forms of communication such as IM. The general feeling is that IM facilitates much more meaningful interactions due to the absence of anonymity. A participant made this comment about IRC: “People don’t put enough thought into what they say, they don’t understand that there are consequences to what they say even though it is not attached to who they are, they don’t understand that just releasing that side of them is not a good thing and that when they are, what it does is take them away from other, higher-quality means of communications and more difficult relationships.” (P4)

3.3.3 Placelessness (C3)

The idea of ‘Placelessness’ was very prevalent in discussions about online communities. CMC media, especially the Internet, give people the ability to move out of their current physical context. The ability to extend the communication past geographical location was identified by several participants and was seen as an excellent way of meeting people from different cultures and countries. As one participant noted that, while physical location no longer restricted who one could talk to, time zone differences were a factor. She said that when she was online, she was more likely to meet people from England, Turkey and the United States, but never New Zealand or Australia, as the different time zones affected who would be online.

Another participant suggested that the virtual world of the internet was an excellent place for “marginalised communities” (P4) to meet. Through the internet people who share similar interests may meet, and discuss ideas, even though they might live many kilometres away. It could be seen that physical location is no longer the defining point for what makes a community. Instead, social interest is the key factor that determines interactions.

3.3.4 Dissociative Interaction (C4)

A prominent factor in CMC is that it does not involve face-to-face interaction. But the higher the degree of dissociation caused by a medium, the more impersonal the communication. Some of the participants noted the irony that while people may be communicating more they are moving apart: “I think it’s ironic that communication has become easier but people are becoming more dissociated with the ease of just pushing buttons.” (P3). So many comments were made relating to the impersonal characteristic of CMC that the theme had to be created as an important additional characteristic.

The delay experienced by users of IM and texting offers them the ability to plan their responses. This was considered a good thing by some participants as they claimed that it would lead to less impulsive responses, by giving people time to control their emotions. Others cited this exact reason as a bad thing, as they claimed that it allows one to falsify the response and lie about what one truly feels. The absence of body language and other nonverbal cues makes lying easier. With this in mind, some of the participants said that to an extent, text based communications could be very superficial as it allows a person to frame the tone and manipulate situations.

This form of misrepresentation can be extended to beyond just changing the tone of the message: “I think people hide in the fact that you can misinterpret tone in text... you can ‘well actually I didn’t mean it like that’...even if you did.” (P5)

Since people are not communicating face-to-face over CMC media they may be instilled with a sense of confidence which was described by some as false. This may lead to people saying things that they normally would not, such as active flirting, or shy people opening up in ways that they are not accustomed to: “There is an enormous factor, in that you are interacting with a computer, who then communicates with another computer on the other side, and so your immediate contact is the computer, which doesn’t seem to make it real, even though the conversation is real.” (P5)

This sense of ‘reduced’ reality also leads to a perceived lack of risk. This may lead to people doing things over IM or text message that would otherwise leave them in an uncomfortable
position: “It offers the sense that of ok if I’m rejected it’s fine… I’m not in that person’s space… they don’t have to watch me be rejected.” (P7)

Finally, because most CMC is text based a lot of meaning is lost: “With text, any text it becomes really hard to show tone and intentions…by talking face-to-face you can get what a person really means, instead of what they just say.” (P5).

3.3.5 Physical Isolation (O1)

CMC was not considered as a substitute for a face-to-face meeting due to the feeling of lack of physical presence. Two participants noted that because of the convenience of CMC people did not see as much of each other as they did previously. They also noted with some disdain that people were less likely to spontaneously visit each other and that there was a perceived need to call before visiting. This could amount to an increase in physical isolation of individuals.

Some participants argued though that in the right context CMC actually helps decrease physical isolation: “I have friends on IM, who I would have had far less visits to their homes if I wasn’t on IM… IM can act as a method of instant invitation because it’s easier and instant.” (P4)

CMC can also help people communicate when they are physically isolated because of circumstance, such as when they are bound to their desk because of work, or have moved to a new location and are far away from family and friends. Webcams coupled with IM were cited as the best means of communicating over long distance as it gave a semi-real physical presence. One participant described how she had moved to America to study, and through the use of a webcam she talked to her brother and parents. She explained at how great the feeling was to see them again; she went so far as to say “It was like being home again” (P6).

It was often mentioned by participants that certain CMC media such as IM could be of great benefit to shy people. They argued that because the conversation was less real, and the threat of physical presence was removed, shy people would be able to communicate more easily. While ‘some’ communication was deemed better than ‘none’, it was noted by several participants that this was “not a means to an end” (P8) for shy people.

While IM and other CMC media can act as a means to help shy people build confidence, it was by no means a cure. It was also often stated that CMC could actually be detrimental to shy people, as they would be encouraged to use IM rather than take part in face-to-face interactions, and would therefore not develop social skills allowing them to meet other people face-to-face. One participant commented on a friend who used to be shy: “The Internet was where he lived like a normal person… I think he would have been better off not living on IRC eighteen hours a day…he could have been developing his face-to-face skills…It has made him think that face-to-face is a whole lot scarier than it really is...” (P4)

3.3.6 Invasion of Privacy (O2)

The mobility afforded by CMC media, especially mobile phones, has enabled people to hold conversations anywhere, including in public spaces. While most participants agreed that it was annoying when people spoke in public, which relates to ‘Etiquette’, it was also a form of forced invasion of privacy. By talking loudly in public places people are giving others the opportunity to listen into their lives. Many participants agreed that the reason people are so likely to discuss private matters in public is because the listener: “…can only hear one side of the conversation... they assume that you can’t fill in the gaps” (DG1)

Another participant commented that she often argued over her mobile in public: “I would carry on fighting with them and crying in public like I don’t care… it’s about the issue in the moment...the only thing that exists is that phone call.” (P7)

Another form of invasion of privacy is inherent in the fact that many people do not switch off their mobile phones; as such people can contact them at any time. “Your time is not yours” (DG1). A consequence of this has been that people are more likely to filter their communications and only choose to respond only when it suits them. Many participants stated that they often feel the need to tell white lies when it comes to being asked if they had received a text message or voice mail message and had intentionally not replied.

3.3.7 Etiquette (O3)

Participants mentioned the chronic lack of courtesy and respect people had when using their mobiles. Talking in public and texting while in the company of others were clearly the biggest issues relating to the etiquette of mobile phone usage. One participant shared a story of how she had been hosting a dinner and one of her guests was texting during drinks, and then continued to talk on his phone and text while at the dinner table. She exclaimed: “It was really rude. It was nothing important; he had no regard for anyone else!” (P3).

It was often suggested by many participants that people have lost respect for others and their physical presence.

An interesting discussion that surfaced frequently centred on how CMC will affect socially acceptable manners. Whilst it was considered extremely rude to have multiple, simultaneous conversations in a face-to-face situation, over IM this was considered perfectly acceptable by most participants, if you were capable of doing it. Some participants said that they did not see it as a problem, since the people they were chatting to were probably doing the same. Similarly, ignoring people intentionally over IM, IRC or text message was considered normal and acceptable: “Yeah, that’s just online etiquette, if you ignore people, it’s socially acceptable.” (P8).

Factors of the CMC media in question which determined what was acceptable and what was not included the length of delay between transmission of messages and extent of dissociation between those communicating. If there is a significant delay between messages then an immediate response was not required and, holding multiple conversations was deemed acceptable. Similarly, the greater the degree of interaction dissociation, the less the attention demanded by the conversation. Voice calling was seen as the least dissociative next to face-to-face communication, followed by IM and IRC, text and lastly email which was seen to be the most dissociative.

Another interesting topic was the content of messages and what would be acceptable to discuss over the different CMC media. People associated different levels of respect to the different media types. The more personal or interactive the media, the more respect it awarded the recipient of the communication. As an example, all the participants agreed that it was unacceptable to break up a relationship over text message. Many cited it as disrespectful, or cowardly.

Email was considered more personal than text message, and while it would be distasteful to break up a relationship over email it was more acceptable. As one participant in a discussion group said: “It would be better to call someone you haven’t seen in a long time, rather than just SMS them, it shows that you value their relationship and respect it.” (DG2)
3.3.8 Deviant Behaviour (O6)

The most discussed form of deviant behaviour was that of paedophilia. Varying discussions on whose responsibility it was to educate children and how to protect them were entered into. It was generally felt that it was up to parents to educate their children and, to a degree, try and monitor their Internet usage. It was often said that it is very difficult to try and teach a child about the dangers of the Internet: “On the internet it’s different, it’s not like talking to a big scary man on the street, and it doesn’t feel like that even though there is a big scary man on the other side of the screen.” (P5).

The younger generation made some interesting comments. They had the general feeling that while paedophilia was prevalent, it was not really a threat. “I think the media sensationalised it” (P8). They also mentioned that children often realise when they are being seduced, and stop the conversation, something the media had not given them credit for. They continued to argue that: “If a child is going to be seduced over the internet then that child has no right to be on a computer, cause they aren’t streetwise enough.” (P8).

When the teenagers were asked about whose job it was to educate the children, they replied that while it was partly the parents’ responsibility, it was also that of the child.

Paedophilia is not the only type of deviant behaviour found over the Internet. Sexual harassment and stalking were also mentioned. When asked why people resorted to the Internet to behave in such a way, participants responded that it was due to the anonymity afforded by the Internet. “There aren’t any rules...there is no public judgment on the Internet” (P4) was stated as another possible reason for deviant behaviour on the Internet.

Another type of deviant behaviour arose in two of the interviews. The fact that people could copy in other people when sending emails was noted as a very effective way of causing trouble. In the one instance a women at a participant’s quilting club started an unfounded rumour concerning the participant and then copied in many of the club members as well as the chairman. While her motivation was unclear it was agreed that she probably would not have done such a thing over a more effort-intensive and personal medium such as a phone call or a handwritten letter. It was suggested that the reason for this action was because the email was less personal and it was so easy to send to many people.

3.3.9 Language Usage (O6)

It was revealed that CMC has had an effect on the language used to convey text-based messages. The biggest change that most people noted was the abbreviation of most words into a series of letters and numbers. Some of the participants thought that the evolving language use was a natural evolution brought about by the fact that one was forced to convey a message in 160 characters or less. One participant also pointed out that writing out messages in full “defeats the purpose of texting” (P6).

Those against the use of the abbreviated form attributed the main fault to the fact that it was too easy to lose meaning, or too difficult to invoke the emotions. It was also pointed out that the abbreviated form might exclude some people from communicating as they are unable to understand what is being said. However, it was raised that meaning could be negotiated and “as long as the message is understood it didn’t really matter” (P1). The abbreviated form is more common in text messages and on IM and IRC than in the other forms of CMC but it is starting to find its way into email. People have developed different styles of the abbreviated form, some participants put this down to an attempt to add character to an otherwise emotionless means of communication, while others looked at it as simply showing that the language had not fully developed and become standardised.

Participants agreed that ‘smileys’ and other emoticons had arisen to compensate for the lack of nonverbal cues. While many of the participants made use of smileys, most of them agreed that they where not very effective as a means of conveying tone. It was said that sometimes smileys could be ambiguous, or misinterpreted, while some participants thought that they could seriously affect the meaning of the message.

The older people interviewed noted that ‘language usage’ and has become more casual over time. Letters used to be signed off with ‘Yours sincerely’ and today many messages end with simply ‘kisses’ or smileys or nothing at all. The formality of the message also goes some way to indicate the amount of effort and intimacy expressed.

While it is unlikely that the abbreviated form will enter into the vocal language, some participants showed dismay at the thought, and even bemoaned the current abbreviated tone: “I feel very threatened by having a cut down language which doesn’t contain longer words that express more complicated emotions, with more nuances and subtleties. I think that it is a way to trap yourself inside your mind with out the ability to express what is really going on, because the borders of your language are the borders of your world.” (P4).

4. SUMMARY OF FINDINGS

When tested, the proposed model as initially constructed failed to account for ‘Dissociative Interaction’ which was prominent in the data. This construct was found to be independent of the characteristic ‘Anonymity’. It impacts ‘Language Usage’ and has a positive influence on ‘Deviant Behaviour’. All other constructs and relationships in the proposed model were found to exist, although the data confirmed that some relationships where not as strong as others and some constructs, for example ‘Placelessness’ did not yield rich results. Figure 2 summarizes the findings.

![Figure 2: Identified impacts of CMC characteristics and outcomes on interpersonal relationships](image-url)
Communities. As more and more marginalised communities
the use of non-verbal cues. The result is a corresponding increase
interpersonal relationships. Consolidating prior research studies, we
found that when tested, the proposed model as initially constructed failed to account for 'Dissociative Interaction' which was prominent in the data. This construct was found to be independent on the characteristics of 'Anonymity' and was found to impact 'Language Usage' and have a positive influence on 'Deviant Behaviour'. All other constructs and relationships in the proposed model were found to exist, although the data confirmed that some relationships where not as strong as others and some constructs, for example 'Placelessness' did not yield rich results.

The refined first-cut model thus provides a valid and holistic view of the characteristics and behavioural outcomes of CMC, their interrelationships and the fact that all of the constructs impact interpersonal relationships. The model will be of interest to anybody who would like to gain a high-level insight into how CMC affects the way people relate to each other. The model conceptualises and presents theoretical constructs in a straightforward, easy to understand manner and as such it could be of interest to academics and laymen alike.

Because the study was limited to South Africa and had a relatively small sample size; further validation of the model is recommended. Specific areas for future research areas are the impact that 'Language Usage' has on interpersonal relationships as not much literature is available on this topic. The extent to which abbreviated forms of text-based messages have led to increased ambiguity and the inability to evoke emotion should also be explored. Finally, the way in which the reduced formality of these messages impacts perceived respect in interpersonal CMC could be studied.

REFERENCES


Principles for successful ICT teaching

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ABSTRACT

This paper describes the investigation process into teaching principles as applied in Information and Communication Technology (ICT). Students in the Faculty of ICT at Tshwane University of Technology were requested to share their views on factors influencing successful teaching in this environment. This was compared to lecturers’ views and also to generic teaching and learning principles as proposed in literature, utilizing grounded theory and relational database concepts. A list of principles was created which can be utilized to evaluate subjects, pinpoint problem areas and guide lecturers in presenting subjects in ICT.

CATEGORIES AND SUBJECT DESCRIPTORS

H.2.4 [Database management]: Systems – relational databases

GENERAL TERMS

Human factors, Design.

KEYWORDS

Teaching principles.

1. INTRODUCTION

Teaching in Information and Communication Technology (ICT) poses many challenges to lecturers, some of which are summarized in Table 1. These challenges are not unique to one university, however, because, as mentioned by the Minister of Education (Pandor, [1]), only one in five students in tertiary institutions in South Africa complete their studies in the stipulated minimum time. Many of these challenges are echoed by Potgieter [2] in an article on the challenges that ICT staff face in Institutes of Technology and Polytechnics in New Zealand.

<table>
<thead>
<tr>
<th>Area</th>
<th>Challenge</th>
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<tbody>
<tr>
<td>ICT environment</td>
<td>Technology develops continuously.</td>
</tr>
<tr>
<td></td>
<td>The theory supporting this technology therefore also changes correspondingly.</td>
</tr>
<tr>
<td></td>
<td>Programming languages change frequently.</td>
</tr>
<tr>
<td>The nature of the subjects</td>
<td>Problem solving is the foundation of all subjects.</td>
</tr>
<tr>
<td></td>
<td>Analysis and design as well as model creation are integral aspects of all courses presented in ICT.</td>
</tr>
</tbody>
</table>

Abstract thinking plays a key role in many subjects.
Almost all subjects must be applied practically.
Many subjects are taught in specialist computer or engineering laboratories.
Lecturers’ levels of lecturer training vary.
Lecturer’s levels of teaching experience vary.
Students are from vastly different personal, educational and technical backgrounds.
The changing educational environment due to South Africa’s recent political changes.
The merging of three independent institutions into a new institution (TUT).
The geographical dispersion of the new institution on 6 learning sites, as well as the re-structuring process and phasing out of teaching on some campuses.

Lecturer training at Tshwane University of Technology (TUT) is focused on generic training and ICT lecturers do not receive formal subject-specific training or support to teach in this challenging environment. They often teach on a trial-and-error basis – which involves learning through their own experience and mistakes.

The objective of this paper is to describe the process followed to create a list of essential teaching principles according to literature, as well as student and lecturer input in

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the ICT faculty at TUT that can be utilized to support lecturers in the teaching process.

The investigation therefore focuses on the teaching principles that are currently applied in teaching in ICT at TUT, as well as the creation of a list of principles which can be utilized in the evaluation of subjects, pinpointing of problem areas and guiding of lecturers in presenting subjects in ICT.

2. BACKGROUND

The ICT discipline is arguably currently one of the most fluent in the academic world, and therefore the definition of the discipline is changing continuously. Clark [3] utilized Biglan’s framework, which focuses on similarities and differences between disciplines on hard and soft (depending on whether the discipline has a body of theory to which all members subscribe or not) and applied or pure (depending on whether the discipline produces knowledge for application or not) dimensions. According to this framework, computer science is a hard-applied discipline – a notion that is supported by research over recent years. The computer science discipline touches on the traditional engineering discipline in the development of electronic devices, but the field of software engineering has also emerged recently. This implies that software – created for businesses, for the internet and for simulations for training (for example) – needs to be developed and based on the types of theoretical foundations and practical disciplines found in traditional engineering disciplines. The ICT discipline, similar to the engineering disciplines, also creates tools for use. The ICT discipline can also be linked to the pure disciplines of mathematics and science, as computer programs follow the logic and algorithms typical of the science disciplines. In recent years, the ICT discipline has also expanded to include business development, web and multimedia development, networking and information management.

The variety and ever-expanding areas covered in the ICT field therefore imply that teaching in this discipline should be well planned and supported by educational principles. Various factors contribute to successful teaching and learning in general, as mentioned by researchers at many universities and other teaching and learning groups. One of these is teaching principles that can be applied to teaching in general. The objective of the remainder of this section is to compile a combined list of these proposed principles from various sources.

The first source is a textbook by Fraser, Loubser and Van Rooy, [4] on didactics, aimed at education students in South Africa. The authors propose the principles of activity, motivation, socialization, individualization, control, planning, perception, totality and science. The second source is a set of nine principles by James and Baldwin [5] that is utilized to guide teaching and learning at the University of Melbourne in Australia in March 2002. These principles are experimentation, intellectual excitement, social context, diversity, individual development, quality learning resources, support, feedback and assessment and adaptive curriculum. Kerns, Elhoua, Sterling, Grant, McGowan, Rubash, Neelly and Wolffie [6], the third source, identifies ten effective teaching principles for classroom teaching with the aid of the Blackboard learning management system [7]. Their principles include an active learning environment, demand for quality, motivation to learn, student-student interaction, student support, faculty-student interaction, timely feedback, focus attention, manage time, connect and organize knowledge.

The fourth source, from Gamson [8], propose seven principles of good practice for undergraduate education, namely active learning, high expectations, cooperation amongst students, diverse talents, student-faculty contact, prompt feedback and time on task. These principles were developed by higher education scholars, led by Arthur Chickering and Zelda Gamson, to improve education at American higher education institutions. The principles combine research findings on teaching and learning experiences over decades. The principles were published after an extensive study by various participants, such as the American Association for Higher Education (AAHE), the Education Commission of the United States and the Johnson Foundation. Responses to the study were extremely positive, and practical guidance on the application of these principles was distributed to many tertiary institutions. Currently, reference is still made to these principles on numerous teaching and learning support sites. These principles were researched and re-applied in many different educational settings, such as for online teaching and learning, computer-assisted teaching and learning, teaching and learning in various subject fields (including engineering, mathematics and languages), lecturer assessment and more, as discussed by Sorcinelli [9]. The resulting list of principles and a description of each is depicted in Table 2.

Table 2. Teaching Principles summary and descriptions

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>The learner should be actively involved in the learning process.</td>
</tr>
<tr>
<td>Motivation</td>
<td>This includes extrinsic as well as intrinsic motivation, intellectual excitement and the demand for quality.</td>
</tr>
<tr>
<td>Socialization</td>
<td>Learner-learner contact and the social context.</td>
</tr>
<tr>
<td>Diversity</td>
<td>Recognize and incorporate differences of learners in the learning process.</td>
</tr>
<tr>
<td>Contact</td>
<td>This entails learner/facilitator/contact and learner support.</td>
</tr>
<tr>
<td>Control</td>
<td>The monitoring of the learning process as well as assessment and feedback.</td>
</tr>
<tr>
<td>Planning</td>
<td>Well-organized learning processes and material.</td>
</tr>
<tr>
<td>Perception</td>
<td>Linking learning material to previous experience and to real life applications.</td>
</tr>
<tr>
<td>Totality</td>
<td>Present a holistic picture of and integrate learning content.</td>
</tr>
<tr>
<td>Science</td>
<td>Subject matter based on pure science of the topic and presented based on the science of teaching.</td>
</tr>
</tbody>
</table>

3. METHODOLOGY

The research described in this paper describes the first cycle of an action research project to improve teaching in the Faculty of ICT at TUT [10]. According to Zuber-Skerritt [11], the purpose of action research is the management of change. She proposes that this change strategy comprise a cyclic repetition of planning actions, executing the planned actions, observing the results of the actions, evaluating or reflecting on the results of the action and then continuing with a newly planned action.

The full research project consisted of four action research cycles. The first cycle investigated the research question posed for this paper: Which teaching principles are currently applied in teaching in ICT at TUT, and which list of principles can be created to be utilized in evaluation of subjects, pinpointing of
problem areas and guiding of lecturers in presenting subjects in ICT? The second cycle utilized the resulting list of principles in the development of a model subject, to investigate how these principles can be applied in teaching in ICT. The third cycle investigated a subject with a low pass rate, to determine whether the application of teaching principles did influence the pass rate. The fourth cycle compared a subject presented in two approaches – one applying the teaching principles successfully and the other not – to determine whether the application of teaching principles can improve the pass rate of ICT subjects. The phases of the action research process, as applied in the first action research cycle – to determine which principles should be included in the list of teaching principles – are described next:

In the planning phase, the project was proposed to and permission obtained from the executive committee of the Faculty of ICT at TUT. The literature survey together with the student and lecturer surveys were planned. This included ethical considerations, question generation, sample selection, and result analysis planning. In the action phase, a student survey as well as a literature survey was conducted. The data gathered in the student survey was processed in the observation phase of the action research cycle, integrating the results of the literature survey into those from the student survey. In the reflection phase, these results were discussed with lecturers identified by students in their survey to refine further the list of principles.

3.1 Data Collection

Senior undergraduate ICT students at the Pretoria campus of TUT were targeted for this phase of the study, because these students experienced the face-to-face teaching environment of the faculty and, as they were all full-time students, they were readily available for participation in the study. Time was allocated during a general meeting of senior students for the discussion, completion and submission of questionnaires. The survey was discussed with the students, including explanations of the purpose of the study, the questions, the importance of their views, voluntary and anonymous participation. No background information about teaching principles was discussed. Of a possible 304 full-time senior ICT students registered at the Pretoria campus of TUT, 151 questionnaires were returned. These were rearranged in random order and numbered from 1 to 151. All the questionnaires were utilized for the survey analysis, but the first 33 (10.8 per cent of all senior students) were processed in more detail to determine students’ perceptions of teaching as applied in the faculty. In the questionnaire, students could first identify the three best lecturers who taught them in their years of study, with reasons for these choices. A second question requested that they should list negative learning experiences (without naming the lecturers). This information was summarized to create a comments list, which was compared to the teaching principles identified by the literature.

A lecturer list was also created, and the nine lecturers who were mentioned positively by most students were targeted for the research. Each lecturer received interview questions via e-mail. Responses were received from all lecturers, via e-mail, hard copy or orally. Follow-up interviews were conducted with some of the lecturers to clarify various issues. The information requested from lecturers covered subject information, lecturer attitude and application of teaching principles.

3.2 Data Analysis

Students were requested to describe aspects of high-quality as well as poor teaching, without introducing them to existing educational theories in this regard. The remarks on the questionnaires were coded systematically. The aim was to develop a list of principles, with no preconceptions of what the ensuing principles would be. (This is reminiscent of the grounded theory research strategy as described by Merriam [12].)

The following guidelines were applied in this process:

- All remarks on 151 questionnaires were considered, in order to create a list of general comments as each new concept presented itself.
- Each general comment was allocated a code word and a short description. For example, the code ‘consistent’ is described as ‘fair in marking and attitude towards students’.
- Similar remarks were coded into the same comment. For example, ‘good explaining’ and ‘present work in an understandable way’ and ‘a student gets to understand what she is teaching’ were all coded as the same comment.
- Each concept was dealt with as a separate comment. For example, ‘he knows his work and knows how to convey it’ was divided into two separate remarks (‘he knows his work’ as well as ‘he knows how to convey it’) and coded into two different comments.
- Each comment was assigned either to be positive or negative, depending on whether it was answering the first or second question.
- Each comment was also linked (where possible) to one of the lists of didactic principles resulting from the literature survey and as depicted in Table 2.

The remarks on 33 questionnaires were further analyzed, through utilization of the comments. After 33 questionnaires, no new information was presented and therefore a saturation point was reached.

In the first question, students could make positive remarks for each lecturer listed. There were 199 positive remarks on the 33 questionnaires that were analyzed in detail. The second question allowed for remarks on negative experiences regarding the teaching and learning process. There were 57 negative remarks. These remarks were coded, utilizing the comment codes as illustrated in the following three examples:

**Example 1**

Student remark: Knows her work.
General comment: Good subject knowledge.
Comment code: Subject knowledge.
Teaching principle: Scientific (Science of subject).
Positive/Negative: Positive.

**Example 2**

Student remark: Present work in an understandable way.
General comment: Good in explaining.
Comment code: Explain
Teaching principle: Scientific (Science of teaching)
Positive/Negative: Positive

**Example 3**

Student remark: Does not have time for students’ problems
General comment: Show interest in students’ personal lives
Comment code: Personal interests
Teaching principle: Contact
Positive/Negative: Negative

**Example 4**

Student remark: Does not give practical exercises in class
General comment: Provides for sufficient practical exercise
Comment code: Exercises
Teaching principle: Activity
Positive/Negative: Negative

A simple relational database was developed in Oracle SQL, to assist in the processing of this data. A relational database model consists of a set of entities that are linked to each other through common characteristics. This provides access to the powerful and flexible structured query language (SQL) which allows for retrieving of data from the database on an ad hoc basis as described by Rob and Coronel [13].

Query examples are:
- A list of all the principles and how many times they are mentioned by students in total. This list must be ordered from most-mentioned to least-mentioned principles.
- A list that indicates how many times each principle is mentioned positively, as well as negatively.
- A list of the ten lecturers mentioned most, as well as how many times each principle is mentioned for each lecturer.

The set of entities is graphically depicted in Figure 1 in an entity relationship diagram (ERD). Each entity and its characteristics and links are discussed after the figure.

The LECTURER entity stores the surnames of all lecturers, their personal numbers, staff numbers. The staff number is used to link this entity to the ANSWER SHEET entity.

The SUBJECT entity contains subject information, including the name of the subject, the subject type (practical work, theoretical or a combination subject) and the unique university code for the subject. It also includes the code of the department to which it is allocated (see the DEPARTMENT entity). The subject code is used to link this to the ANSWER SHEET entity.

The COMMENT entity is used to capture the characteristics of the various general comments. It consists of a short comment name, a comment type (whether it is positive or negative) and a comment description. It also includes the code of the didactic principles from the DIDACTIC entity. If the comment cannot be linked to a value in the DIDACTIC entity, this code is indicated as 00. Lastly, it includes a unique comment code, created by the researcher. The comment code links this to the ANSWER SHEET entity.

The ANSWER SHEET entity was created as a link between the positive remarks from students and the subject entity, as well as the lecturer entity. This was necessary, as each answer sheet could consist of various remarks on a variety of subjects and lecturers. The entity consists of the unique number for each answer sheet (the numbers 1 to 33 as numbered by the researcher), the lecturer’s staff number (linking it to the LECTURER), the subject code (linking it to the SUBJECT) and the comment code (linking it to the COMMENT). This implies that if a student mentioned three different lecturers in the first question, with two positive remarks about each lecturer, this entity will have six remark entries for the specific answer sheet.

3.2.1 Student Input

In the coding of student remarks into comments, it is clear that students’ views on successful teaching principles correspond closely to the principles described in the literature. Students mention nine of the ten principles in Table 2. The only principle that is not mentioned directly by any student is that of socialization (student-student interaction in the learning process). It is not clear if this is due to the way the questions were posed or if it was not applied regularly as a teaching strategy in classes. This aspect will be investigated in further research cycles.

A query to list students’ remarks against the teaching principles yields the results as depicted in Figure 2. Data was obtained from the COMMENT, ANSWER SHEET and DIDACTIC entities.

Figure 1. Entity relationship diagram

The DIDACTIC entity represents the didactic principles resulting from the literature survey and depicted in Table 2. It consists of three columns, namely a principle name, a short description of the principle and a unique code for each principle. This code is used as link to the COMMENT entity.

All lecturers and subjects in the faculty of ICT are allocated to specific DEPARTMENTS. A lecturer may, for example, be allocated to one department, but may present a subject that is linked to another department. The department entity lists the names of departments in the faculty of ICT responsible for presenting subjects. It also depicts a unique code for each department created by the researcher. This code is used to link to the LECTURER as well as to the SUBJECT entities.

The LECTURER entity stores the surnames of all lecturers, the code of the specific department to which he/she is allocated (see the DEPARTMENT entity), as well as the lecturers’ unique

Figure 2: Student remarks per principle
From Figure 2, it is clear that students value the scientific principle as the most important principle. This principle implies that lecturers should know the science of the subject itself and be well-prepared for classes, but should also know the science of teaching and therefore be able to transfer their knowledge successfully to students. If this principle is split into two separate principles, namely the science of teaching as separate from the science of the subject, it may yield more information in this regard. This will be investigated in further cycles.

The principle of motivation is also regarded as important, implying that lecturers should convey to students their own love of the subject and of teaching, and inspire them through fair practices, but also in the high standard and professionalism of their own work and in high expectations from students.

The third most important principle, according to students, is that of contact between the faculty and students. This includes aspects such as lecturers being approachable and available for consulting and provision of sufficient and relevant support and support material. Diversity implies, according to student remarks, not only the recognition of differences between students and their abilities and interests, but also implementation of teaching strategies to support this. On the other hand, it also entails the desire to be treated equally – race and language were mentioned frequently here. The principle of control features in remarks such as control over the teaching process, where a variety of assessment procedures with timely and relevant feedback is deemed as being of great importance. On the other hand, it also refers to control over a group of students in the teaching process, as well as professional and controlled conduct by the lecturer.

Students appreciate lecturers’ ability to teach with real-life examples, linking their studies to their future jobs. On the other hand, the importance of placing current content in the correct perspective regarding their studies – linking it to and building on previous knowledge, as well as to other subjects – is also mentioned. This is identified as the principle of perception.

The principle of activity is not mentioned by many students, but those who do so refer to aspects such as sufficient exercises of high standard, opportunities to explore new concepts on their own, student-centered classroom as well as homework activities, and the application of problem solving as teaching strategy. Many students criticize lecturers who read from textbooks or slides, as well as lecturers who use practical sessions for direct instruction (lectures). The principle of planning also does not feature much, but those students who mention it refer to issues such as the provision of and adherence to a schedule and the objectives set out for the subject. Totality as a principle was only mentioned by a few students, referring to the ability to generate the bigger picture for a subject. From students’ comments, it also is clear that the principles of control and planning may be closely related, since both principles address similar concepts, namely timely feedback, time management and control of the learning process. This will be investigated in further research.

### 3.2.2 Lecturer input

To reflect on and refine the list of principles and also to triangulate the data, structured interviews were conducted with specific lecturers as identified by students. The principles were also presented to and discussed with other lecturers in the faculty at various meetings. The nine lecturers identified by most students in the questionnaires were approached to participate in the unstructured interviews. The information requested covered subject information, lecturer attitude and application of teaching principles. Table 3 summarizes the feedback from lecturers per question.

<table>
<thead>
<tr>
<th>Nr</th>
<th>Question</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Subjects: Level</td>
<td>Subjects ranged from first- to third-year level.</td>
</tr>
<tr>
<td>2</td>
<td>Subjects: Type</td>
<td>The subjects covered the full spectrum of topics covered in the faculty.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It also included practical, theory, technical and problem solving, face-to-face as well as blended modes.</td>
</tr>
<tr>
<td>3</td>
<td>Formal training</td>
<td>Of the nine lecturers, four completed formal teacher training.</td>
</tr>
<tr>
<td>4</td>
<td>Attitude</td>
<td>All the lecturers replied that they see teaching as a calling rather than a job and that they enjoy working with students.</td>
</tr>
<tr>
<td>5</td>
<td>Application of teaching principles</td>
<td>All the lecturers indicated that they apply most or all of the teaching principles, even though most of them do not consciously decide to do so; neither did they know the formal descriptions of these principles before the interview. Principles are applied as the situation dictates. Sometimes it is carefully planned, but in other cases it is applied as a result of ‘gut feeling’.</td>
</tr>
</tbody>
</table>

The information about subjects and levels was requested to determine the mode (practical, theory, combination) and difficulty level of the subjects in which these lecturers are involved.

First, it should be noted that the subjects indicated by the students in their remarks about these lecturers covers the full range of subjects taught in ICT – many of which are on the higher cognitive levels (programming and design, as well as the technical subjects taught in computer systems engineering). Pass rates of these subjects were also investigated. Results of these successful lecturers are fairly good. Pass rates in the region of 80 per cent, with class averages of 50 per cent and higher, are reported by most of the lecturers interviewed.

The main exception is mathematics, where students’ comments are positive for all mathematics lecturers, but the pass rates are generally below 50 per cent. These lecturers, however, indicated that they do not apply the principles of activity, perception and totality – which may be the reason for this. Many other factors, such as the subject compilation and students’ mathematical background, may have a major influence on the pass rate. This was not investigated further in this research.

During the discussions with these lecturers, it was evident that all of them love teaching and that this is their first choice of profession. Some of the comments in this regard include ‘I love teaching students new concepts and seeing that they grasp it’; ‘I really love it!’; ‘Teaching is a wonderful way to change somebody’s life and to prepare that person for a productive future’; ‘I love to see the light dawn in their eyes when they grasp a new concept’; and ‘I like to help prepare them for the private sector’.

All lecturers agreed that these principles are of utmost importance for successful teaching, and that a balanced combination is necessary, not only during formal classes, but also in all other dealings with students. Many of the principles are applied based on conscious planning, but other principles are applied sub-consciously.
All lecturers indicated that they apply the principles of science, motivation, contact, and control, while eight of the nine also apply the principles of socialization and planning.

### 3.2.3 Integrated Summary

All ten principles suggested by the literature and as summarized in Table 2 are identified as of importance by lecturers and students – some less and some more so. (It does not seem as if the level [first to third year] or the type of the subject [practical, theory, technical, problem solving] play any role in these results.) The top three principles in the students’ list, namely the principles of science, motivation, and contact, also top the lecturers’ list of principles.

Another prominent principle in lecturers’ comments, as well as in student remarks, is the principle of contact between faculty and students. Based on the students’ remarks about the successful lecturers, it seems as if there is a good relationship between students and these staff members. Remarks such as ‘approachable’, ‘fair’, ‘friendly’, ‘understands students’, ‘treats all students the same’, ‘is a mentor’ and ‘kind’ confirm this. Some of the negative remarks hint of the opposite for other lecturers, for example, ‘no respect for students’, ‘negative attitude towards students’, ‘lack of communication skills’, ‘impatient’ and ‘moody’. The majority of the negative remarks can be linked to contact.

The principle of socialization, which is not mentioned by the students directly, is mentioned quite strongly by most lecturers. Examples are ‘Group work is VERY important’ and ‘Socialization is very important. It brings students closer together, which is important as they tend to understand explanations from their peers better. It also improves their confidence, especially in the programming phases’.

It is interesting to note that lecturers emphasize the principles of planning and control much more than the students. It may be because they are responsible for these and that students do not notice them so much in a well-designed subject. The fact that students did not often mention the totality and perception principles may be either because lecturers do not apply the principles successfully (as indicated by some of the lecturers), or that students may not be aware that these principles are applied in the teaching process. In discussions with members of the faculty’s advisory committees on teaching and learning, however, it is often mentioned that students entering the workplace do not seem to have a holistic picture of what they have studied, and neither do they seem to understand that their studies have prepared them for their day-to-day jobs. This is an indication that more emphasis should be placed on these principles in the teaching process. The application of these principles will be investigated in further cycles of the research.

The principles of activity and diversity are also not highly emphasized by either students or lecturers. The importance of these principles will be investigated in further research cycles.

### 3.3 Result

The result of this research is a list of teaching principles which is applied in ICT at TUT, according to students and lecturers, and integrated with principles as proposed by literature.

Table 4 summarizes the list of principles and suggestions for further research as discussed in the previous section and as applied in the ensuing action research cycle of the over-arching project.

<table>
<thead>
<tr>
<th>Nr</th>
<th>Principle</th>
<th>Sub Principle</th>
<th>Suggestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Science</td>
<td>Science of</td>
<td>Separate principle</td>
</tr>
</tbody>
</table>

The list of principles was presented to lecturers at a workshop on improving throughput. Lecturers agreed with the list and the importance of all of these principles. Many lecturers, however, indicated that they do not apply all the principles in their teaching, and that they would appreciate support in the application of these principles in the teaching of ICT subjects.

The remainder of the action research process, which is not described in this paper, applied and refined the list of teaching principles in various subjects, selected on a variety of selection criteria such as the pass rate, content type (practical / theoretical / technical), nature (abstract thinking / problem-solving nature), and teaching mode (online / face-to-face / blended). The principles were utilized to develop a subject, pinpoint problems in a subject with a low pass rate, and determine a best-practice presentation mode for a research subject.

### 4. CONCLUSION

This paper describes the first phase in an action research project, during which a list of teaching principles was created, based on input from literature, as well as students and lecturers in the faculty of ICT at TUT. This list of principles was applied and refined in a variety of circumstances, to evaluate its relevance, especially in the challenging ICT and educational environment.

During this project, a process was developed [10] that can be utilized to support teaching improvement in the following areas:

- The pinpointing of specific problems in subjects
- Improvement of ‘problem subjects’
- Support lecturers
- Train new lecturers

The core of the process is the application of these principles. This process was applied in pinpointing problems in two fourth year subjects, to improve teaching in one computer systems engineering subject and in the support of various lecturers in teaching aspects. New lecturers in the faculty of ICT were also guided in their first semester of teaching via these principles as a basis for further development of teaching skills. The process was also applied in the evaluation of a training simulation application developed for safety training in the mining environment, created by Multimedia students.

Although the process was applied in a variety of environments with success, future research should investigate and improve this process itself.

These principles can therefore be successfully applied to the advantage of teaching improvement in a variety of applications in the challenging ICT environment.
REFERENCES


The inclusion of a Software Testing module in the Information Systems Honours course

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ABSTRACT
The IS Honours course in the Department of Information Systems at the University has a strong bias towards Information Systems Development. Systems Analysis, Design and Implementation are an integral part of the curriculum. Software testing as a stand-alone module, however, has not been included in the curriculum. It is often seen as the pariah of Systems Development.

This paper briefly investigates the reasons for including a Software Testing Module in 2008, and the proposed Software Testing curriculum for Information Systems students. The paper then continues to cover the manner in which Software Testing is introduced to the students at the Information Systems Honours level and how it will be taught, practiced and assessed.

KEYWORDS

1. INTRODUCTION
Software Quality and Software Testing concepts have been an integral part of the courses offered in the Information Systems Department and they have been inherently included in the course material for Systems Analysis, Systems Design and Systems Implementation. However, as the course content for these modules has been reviewed and new lecturers assigned to teaching them, the emphasis on testing has been lost. Drake (2003), Jones (2004) and Tang, Poon & Chen (2005), concur that less emphasis has been placed on Software Testing in comparison with other development life cycle activities. The aim of this paper is to discuss why and how, a new module on Software Testing has been integrated into the Information Systems Honours Course.

2. BACKGROUND OF THE UNIVERSITY AND INFORMATION SYSTEMS DEPARTMENT
The University is a public higher education institution with an annual enrolment, of approximately 6000 students. The Department of Information Systems is housed in the Commerce Faculty. Current enrolment in the department is approximately 360 students of which 23 are registered for IS Honours or the fourth year of study.

Two main themes of the Department at both undergraduate and postgraduate levels are Systems Development and IS Management. Since the IS Honours programme was introduced in 1991, the curriculum has not included Software Testing as a stand-alone module. It was proposed that Software Testing be incorporated as a module to be taught independently of other modules at the IS Honours level.

3. TESTING THE SYSTEM
Pfleeger & Atlee (2006) explain that testing a system is very different from unit and integration testing. With unit testing – the developer has complete control of the process. When a system is tested, one would work with the entire development team. Too often, testing is understood as program testing, and one wonders why the entire system has been rejected when each of the programs actually work. (Pfleeger & Atlee, 2006)

According to Pfleeger & Atlee (2006), the objective of unit and integration testing was to ensure that the code implemented the design properly. In system testing, however, there is a different objective to ensure that the system does what the customer wants it to do. To understand how to meet this objective it is important to understand where faults in the system come from. (Pfleeger & Atlee, 2006)

In order to establish an acceptable module on Software Testing, students should be encouraged to realise the importance of software testing. Once the relevance of the module has been established a student should be more focused on finding out how to carry out the software testing process.

3.1 Software Testers
Jones (2004) believes that often student enroll for a course because they need the extra elective and not necessary because they have a particular interest in the course. His belief is that teaching of Software Testing should be integrated throughout the curriculum rather than in one course. My belief is that if a greater emphasis is placed on the importance of the module – one might produce better Software Testers.

1 Email: l.palmer@ru.ac.za
3.2 Examples of Testing Careers in South Africa

Software testing is becoming a highly sought after profession and a career in this area can be very lucrative. Students should be made aware of the job profile and opportunities in industry. This might ensure that students will be more serious about wanting to undertake a course in Software Testing. Table 1 contains two job advertisements for Software testers in South Africa. The salaries are very competitive and comparable to similar jobs in Systems Analysis, Design and Implementation.

<table>
<thead>
<tr>
<th>Software Testing Job Advertisements found on the Internet (March 2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref No: gz17654s</td>
</tr>
<tr>
<td>Software Testing Services Company based in Johannesburg requires a Senior Analyst to ensure the quality of application delivered for a specific work stream or project.</td>
</tr>
<tr>
<td>B.Sc Degree/ B.com in Accounting with 3 years testing experience. Experience to include automated testing knowledge utilizing Mercury Tester, (Lab and Plan), Rational Test Manager and Test Real time or similar tools essential with QTP skills advantageous.</td>
</tr>
<tr>
<td>Reference Number: gz17654A. Permanent position offering a salary of R280 to R340k per annum negotiable. Company will consider contract appointments at a rate of R250 per hour negotiable</td>
</tr>
<tr>
<td>Area: Johannesburg</td>
</tr>
<tr>
<td>Online: <a href="http://www.e-merge.co.za/new/emerge.cfm?x=selectopp&amp;cat=48">http://www.e-merge.co.za/new/emerge.cfm?x=selectopp&amp;cat=48</a></td>
</tr>
</tbody>
</table>

Table 1

4. BACKGROUND FOR INCLUDING A SOFTWARE TESTING MODULE IN 2008

The Information Systems Honours programme has several components that are inextricably interlinked. Some modules are seen to support specific aspects of the course, while others are core modules which produce skills and values which are perceived to be invaluable in the workplace, and also a highly desirable quality of a graduate from this University.

Members of the Rhodes University Information Systems Advisory Board, together with staff members, have discussed the need for a clearer focus on software testing aspects in the curriculum. Historically, new teaching material is introduced at the second or third year levels of teaching in the department. However, it was proposed that the new Software Testing module be introduced as an independent module at the Honours level.

4.1 Systems Development team structure and roles for 2008

The manner in which of the Systems Development Projects are carried out, was changed in 2007. Each Systems Development team consists of six members, who are each assigned two roles in their respective project team. The team structure has been modified to include five distinct development roles, which are:

1. Project Manager
2. Analyst (Requirements Elicitation and Analysis)
3. Designer (Logical and Physical Design)
4. Implementer (Programming)
5. Software Tester (testing at all levels of the systems development life cycle)

Each team member is assigned to two of these development roles, according to their individual strengths and/or preferences. Each project team consists of one project manager, two analysts, two designers, four implementers and three testers. The proposed Software Testing module is essential for the students who have been assigned to the Software Tester role in the Development teams. However, students may select the module as an elective, even if they are not “testers” in the development project.

The Information Systems course outline is shown in Table 2 below.

<table>
<thead>
<tr>
<th>Information Systems Honours Course outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research Project - valued at 20% or 30% (Choice *)</td>
</tr>
<tr>
<td>2. Systems Development Project - 20% (* If 20% Research Project was chosen)</td>
</tr>
<tr>
<td>3. Twelve Coursework Modules broken down as follows:-</td>
</tr>
<tr>
<td>a. Two compulsory core modules worth 2.5% each - (Total = 5%).</td>
</tr>
<tr>
<td>b. One compulsory module worth 10%. (Total = 10%)</td>
</tr>
<tr>
<td>c. Three elective modules are worth 10% each - (Total = 30%)</td>
</tr>
<tr>
<td>d. Six elective modules are worth 5% each - (Total = 30%)</td>
</tr>
<tr>
<td>o [Three of these are support modules.] The three 5% support modules are;</td>
</tr>
<tr>
<td>• Requirements Management,</td>
</tr>
<tr>
<td>• Software Testing,</td>
</tr>
<tr>
<td>• Development Tools.</td>
</tr>
</tbody>
</table>

The support modules are intended to provide support for the Systems Development roles. (Students must choose at least one of these)

Table 2

4.2 Who is doing the Module?

There are twenty seven students registered for the IS Honours degree in 2008. Twenty four of these students have elected to do the Systems Development Project and of these, fifteen students have elected to take the Software Testing Module. Several of the students who are doing 30% research, instead of the Systems Development Project, have elected to do the Software Testing Module as well – giving a total of seventeen students who are registered for this module in 2008.
4.3 Systems Development Approach and Deliverables

The Rational Unified Approach (RUP), using the Unified Modeling Language (UML) has been adopted as the development approach. The RUP approach is iterative and incremental in nature, and teams are expected to develop their systems over several iterations. Each iteration covers the full systems development life cycle. (Stumpf & Teague 2005: 31-65).

Microsoft’s Visual Studio Team Suite (VSTS) has been identified as the working environment for the project, and students are expected to adopt this environment which encourages team work and integration. Other software tools that are being used are Rational Requisite Pro and Rational Rose.

On the completion of each of the iterations the following documents are produced by respective team members as deliverable:

- Project Management documentation
- Systems Requirements Specification documentation
- Design Documentation
- Implementation documentation
- Software Testing documentation
- Demonstration of the system for assessment

4.3.1 Software Testing – Text and Module Outcomes

As can be seen, Software Testing is very closely aligned to the Systems Development Project and the emphasis of the module should be to follow the Systems Development Life Cycle and the manner in which the Systems Development Projects are carried out.

The text which has been chosen for the module is “Foundations of Software Testing”; [ISTQB Certification] by Dorothy Graham, Erik Van Veenendaal, Isabel Evans and Rex Black (2007). This book was selected because it meets the outcomes that were identified for the student to gain a better understanding of the concepts and principles of Software Testing and not just the Software Testing techniques. The Software Testing Model in the text is well aligned to the Iterative Rational Unified Process (RUP) approach, which is followed in the Systems Development Project.

4.3.2 General Outcomes

The general outcomes for the module display the characteristics that student should acquire if the module is presented in the correct manner.

At the conclusion of the module the student will be expected to:

1. identify and solve problems
2. work in a team
3. organise and manage him/herself
4. collect, analyse and evaluate information
5. communicate effectively
6. use science and technology
7. recognise problem solving contexts
8. participate as a responsible citizen
9. be culturally and aesthetically sensitive.

4.3.3 Specific Outcomes

Specific outcomes are related to the module content, and not necessarily the manner in which the content is presented to the students. They display the knowledge and necessary skills which the student should possess, after completing of the module.

At the conclusion of the module, students should be able to:

1. appreciate why Software testing is necessary,
2. explain the fundamental principles in testing, recall the common objectives of Software testing and describe the purpose for testing during Software Development,
3. recall the fundamental test activities from planning to test closure activities and the main task of each test activity,
4. understand that the success of testing is influenced by psychological factors and be aware of the different mindsets of testers and a developers,
5. remember the concept of Software Development Models and recall reasons for different levels of testing and the characteristics of good testing in any life cycle model,
6. compare the different levels of testing, and have a clear understanding and purpose of the four software test types,
7. distinguish the difference between Static and Dynamic testing techniques,
8. identify test conditions and design test cases,
9. explain the characteristics and differences between specification-based testing, structure-based testing and experience based testing,
10. discuss the factors that influence the selection of the appropriate test design technique for a particular kind of problem,
11. organise the testers and the testing, and estimate, plan & strategise the test effort,
12. test progress monitoring, test reporting and test control,
13. appreciate the affect that testing has on the product and project risk,
14. discuss how to manage incident management and write incident reports,
15. make use of software testing tools and techniques in their role as testers in the Systems Development Project.

5. TEACHING AND ASSESSMENT OF THE MODULE

5.1 Software Testing Content

The content of the Software testing module will be strongly influenced by the text book which has been chosen:

- Fundamentals of testing
- Testing throughout the software life cycle
- Static techniques
- Test design techniques (Dynamic Testing)
- Test management
- Tool support for testing
5.2 Contact Hours
Typically a 5% IS Honours module has 10 contact hours scheduled for teaching. However, the students are expected to prepare work before each of the lectures so that constructive discussions can take place in time allocated after each lecture session. The total number of hours that a student should spend on a module of this nature would be between 30 and 40 hours.

5.3 Teaching style
All of the teaching staff in our Department has the freedom to exercise their own teaching style and method, especially at the Honours level. At the Honours level – my lectures are informal. The informal atmosphere encourages discussion and participation from the entire class. The venue will be more intimate, with the tables set out in a U shape to facilitate discussion. I believe when everybody around the table contributes to the conversation a lively debate will ensue and the topic will be explored and challenged more deeply and is more likely to be remembered. Knowledge is assumed and remembered far more readily in a relaxed environment. The Software Testing module this year with only 16 students is the ideal situation for this style of teaching.

At the start of the module, the students will be given the Outcomes Based Document which includes the general and specific outcomes for the module, and details of the reference material required for the module. They will also have access to a detailed module specification with lecture times and content for each lecture.

The first four lectures will be presented in a formal manner by the lecturer, followed by discussions. These lectures are intended to ensure that the students are familiar and at ease with the fundamentals of testing and the concept of testing throughout the life cycle. These sessions are crucial, as the students need to engage with the subject completely.

Students are placed into teams of between two and five members, and topics are allocated to each team. The topics will follow the module outline, and the students will be required to prepare a presentation on their assigned topic, which they will present to the class. The students are also required to read a pre-assigned article, which relates to the topic to be presented on the day. Each presentation will be followed by class discussion and debate, facilitated by the lecturer. The presenting team is required to produce a formal, written assignment of the material covered. The presentation material and written assignments will be placed onto the module web page for fellow students to access.

The module web page also has links to extra readings and articles that are relevant to the module. These readings are selected and placed onto the web page by the lecturer in charge of the module.

5.4 Assessment
The students are assessed throughout the module. Each presentation is assessed and the assignments which are handed in are also formally assessed. Class participation is noted and a mark assigned to each student for his or her active participation during the discussion sessions. A formal examination will be written during the examination period at the end of the year. Exams for the 5% Honours modules are usually 90 minutes in length.

Most of the students who have elected to do the Software Testing module will have tester roles in the Systems Development teams. Deliverables produced for each iteration of the systems development projects are assessed. Marks for these deliverables are assigned to the students responsible for their roles in the project.

6. REFLECTIONS
The content for teaching modules is extremely important. The experts in this field have produced extremely good texts and reference material. Software testing is a very big topic and it is understood that the students can only be exposed to a small amount of material during the presentation of the module. The challenge for the lecturer is to instill a desire in the students to learn more about the topic and encourage the practice of this specific discipline once they get into industry. Facts and skills can only be obtained once this desire has been unleashed. It is my intention to get the students to recognize the importance of Software Testing.

7. CONCLUSION
This paper discussed the ideas and thoughts for presenting a module on Software testing at the Honours level. The background, reasons and significance for teaching this module are discussed. The module outcomes have been outline, and the manner in which the lecturer plans to teach this module is articulated. Assessment of the module is not fully contained within the confines of the module, as it is a support module for the Systems Development Project. The reflections of the lecturer recognises that this topic is extensive, and the aim of the lecturer is to instill, in the students, a desire to learn more about Software Testing once they are in the workplace.

REFERENCES
Teaching the Theory of Formal Languages and Automata in the Computer Science Undergraduate Curriculum

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School of Computer Science, University of KwaZulu Natal, Pietermaritzburg Campus

ABSTRACT
The theory of formal languages and automata form an essential component of the undergraduate Computer Science curriculum both nationally and internationally. This paper reports on the experiences of teaching the theory of formal languages and automata at universities worldwide. The paper discusses how this area is incorporated into the Computer Science undergraduate curriculum, teaching and learning difficulties generally encountered, different teaching methodologies employed and teaching and learning aids. The paper also identifies further areas of research into improving the teaching and learning of the theory of formal languages and automata.

CATEGORIES AND SUBJECT DESCRIPTORS
K.3.2 [Computers and Education]: Computer and Information Science Education – computer science education, curriculum.

GENERAL TERMS
Computer Science Education.

KEYWORDS
Theory of formal languages, automata theory.

1. INTRODUCTION
This paper aims to bring together different experiences in teaching and learning theory of formal languages and automata at universities worldwide. As such it provides a reference for academics teaching this material for the first time and for those who wish to further develop and improve their courses on formal language and automata theory (FLAT).

Research into the teaching and learning of FLAT is a well established area of Computer Science Education research and a session is often dedicated to this topic at the annual ACM SIGCSE (Special Interest Group on Computer Science Education) conferences with the SIGCSE ’06 including a panel discussion on the teaching of automata [1]. As mentioned above this paper provides a survey of experiences in teaching and learning FLAT and also highlights future areas of research for improving the teaching and learning of this topic. As such the paper will also serve as a reference for new and current researchers in this field.

The following section provides an overview of how FLAT topics are incorporated into an undergraduate Computer Science curriculum. This is followed by a discussion on the learning and teaching difficulties generally experienced at universities with FLAT courses. Teaching methodologies and aids employed to overcome these problems are then presented.

Finally, the paper identifies areas for further improvement of the teaching and learning of FLAT.

2. FLAT IN THE COMPUTER SCIENCE UNDERGRADUATE CURRICULUM
The Computing Curricula report for Computer Science composed by the ACM and IEEE [43] outlines which FLAT topics are core topics and must form part of the Computer Science undergraduate curriculum and which areas are electives. Table1 lists the core topics and Table 2 the electives.

<table>
<thead>
<tr>
<th>Table 1: Core FLAT topics described in the Computing Curricula report</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic Computability</strong></td>
</tr>
<tr>
<td>• Finite-state machines</td>
</tr>
<tr>
<td>• Context-free grammars</td>
</tr>
<tr>
<td>• Tractable and intractable problems</td>
</tr>
<tr>
<td>• Uncomputable functions</td>
</tr>
<tr>
<td>• The halting problem</td>
</tr>
<tr>
<td>• Implications of uncomputability</td>
</tr>
</tbody>
</table>
A survey of the undergraduate Computer Science curricula taught at universities nationally and internationally was conducted via the Internet. Approximately fifteen curricula were reviewed. The survey revealed that a majority of both the core and elective topics are taught to undergraduate students. In most institutions a course on FLAT is taught in the third year of a three year undergraduate degree. At some universities these topics are taught over the second and third year and at a few institutions basic FLAT concepts are included in first year courses. FLAT courses include additional topics such as parsing or cellular automata. Table 3 tabulates the topics, in order of complexity, that were found to be common to most FLAT modules and some of the additional topics taught. FLAT courses usually have a Discrete Mathematics prerequisite due to the mathematical nature of the course. In a number of universities the FLAT course is a prerequisite for a fourth year course on Compilers and Programming Languages.

Table 2: Elective FLAT topics described in the Computing Curricula report

<table>
<thead>
<tr>
<th>The Complexity Classes P and NP</th>
<th>Automata Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Definition of the classes P and NP</td>
<td>• Deterministic finite automata (DFAs)</td>
</tr>
<tr>
<td>• NP-Completeness (Cook’s theorem)</td>
<td>• Nondeterministic finite automata (NFAs)</td>
</tr>
<tr>
<td>• Standard NP-complete problems</td>
<td>• Equivalence of DFAs and NFAs</td>
</tr>
<tr>
<td>• Reduction techniques</td>
<td>• Regular expressions</td>
</tr>
<tr>
<td></td>
<td>• The pumping lemma for regular languages</td>
</tr>
<tr>
<td></td>
<td>• Pushdown automata (PDAs)</td>
</tr>
<tr>
<td></td>
<td>• Relationship of PDAs and context-free grammars</td>
</tr>
<tr>
<td></td>
<td>• Turing machine</td>
</tr>
<tr>
<td></td>
<td>• Nondeterministic machines</td>
</tr>
<tr>
<td></td>
<td>• Sets and languages</td>
</tr>
<tr>
<td></td>
<td>• Chomsky hierarchy</td>
</tr>
<tr>
<td></td>
<td>• The Church-Turing Thesis</td>
</tr>
</tbody>
</table>

Table 3: FLAT topics that form part of undergraduate Computer Science curricula

<table>
<thead>
<tr>
<th>Common Topics</th>
<th>Additional Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Deterministic finite automata (DFAs)</td>
<td>• Pumping lemma for context-free languages</td>
</tr>
<tr>
<td>• Nondeterministic finite automata (NFAs)</td>
<td>• Parsing – top-down parsing, bottom-up parsing, LR, SLR, LALR parsers</td>
</tr>
<tr>
<td>• Finite transducers (Mealy and Moore machines)</td>
<td>• Set theory</td>
</tr>
<tr>
<td>• Converting NFAs to DFAs</td>
<td>• Cellular automata</td>
</tr>
<tr>
<td></td>
<td>• Cryptography</td>
</tr>
<tr>
<td></td>
<td>• L-systems</td>
</tr>
</tbody>
</table>

The instruction of FLAT courses takes the form of a combination of lectures and weekly tutorials. Traditional chalk-and-board methods are used to teach students the different concepts during lectures. Lectures are based on a prescribed textbook. Table 4 lists the textbooks generally prescribed in FLAT courses in order of popularity. These courses are taught without the use of computers and usually do not include any programming [27]. Tutorials require students to work through exercises which are submitted for assessment and the marks obtained for the tutorials usually contribute to the class mark for the course. Other forms of assessment commonly used in FLAT courses include tests during the semester and an end-of-semester examination. A few FLAT courses include a practical project such as the construction of a scanner for a compiler. However, this is rare and is usually included in courses that present additional topics such as parsing.

Table 4: Textbooks commonly prescribed in FLAT courses

<table>
<thead>
<tr>
<th>Book Title</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to the Theory of Computation</td>
<td>(Sipser, 2005) [35]</td>
</tr>
<tr>
<td>Introduction to Automata Theory, Languages and Computation</td>
<td>(Hopcroft, 2006) [21]</td>
</tr>
<tr>
<td>An Introduction to Formal Languages and Automata</td>
<td>(Linz, 2006) [25]</td>
</tr>
<tr>
<td>Introduction to Computer Theory</td>
<td>(Cohen, 1997) [11]</td>
</tr>
</tbody>
</table>

The following section describes difficulties experienced by both lecturers and students involved in FLAT courses.

3. TEACHING AND LEARNING DIFFICULTIES

FLAT topics have been found to be difficult to teach and learn ([6], [7], [26], [42]). Students generally find FLAT courses to be outdated and cannot relate them to other courses in the
Computer Science curriculum or current computer applications ([23], [39]). Thus, students taking a FLAT course tend to be disinterested and are not motivated.

Due to the mathematical nature of the course students find the topics covered abstract and difficult ([14], [39], [40], [41]). The traditional chalk-and-board teaching methodology employed to teach FLAT courses makes it difficult for students to conceptualise the different structures and proofs ([9], [26]). The paper tutorials do not facilitate immediate feedback and are not interactive which also makes learning difficult ([5], [14], [31], [39], [40]). Verma [39] states that this often leads to student frustration and a higher drop-out rate for FLAT courses than other Computer Science courses. Furthermore, these difficulties often result in students obtaining a “superficial” understanding of FLAT concepts [7]. This point was further emphasised by student evaluations conducted by the author in a third year undergraduate course on FLAT, in which some students commented that they had not obtained a deep enough understanding of proofs.

On the one hand lecturers have to deal with de-motivated and often frustrated students. In addition to this marking of written tutorials submitted by students is difficult and time-consuming to mark by hand and the process is error prone. The following section discusses methods employed to overcome these difficulties.

4. TEACHING STRATEGIES

Given the problems outlined in the previous section, a lot of research has been conducted into improving the teaching and learning of FLAT courses. Constructivist teaching methods which require students to learn by doing and using and building on existing knowledge of concepts are replacing the traditional chalk-and-board methods which facilitate passive learning. Such constructivist methods promote active learning which is important in Computer Science [42].

A number of visual tools that can be used for both teaching and learning have been developed to motivate students and help them obtain a deeper understanding of FLAT constructs and proofs.

Learning tools that provide individualised student tuition, namely, intelligent tutoring systems, are also being investigated as a means of assisting students to overcome learning difficulties with FLAT.

Attempts have also been made to increase students’ interest by using current Computer Science applications to discuss the different concepts. The inclusion of historical information on FLAT in courses has also proven to simulate student interest.

Chesnevar et al. ([7], [8]) have found that a combination of using visual tools, relating FLAT concepts to other Computer Science topics and current applications and providing an overview of the role played by FLAT in Computer Science history, is effective in motivating students and helping them conceptualise the different FLAT concepts. These different approaches are discussed in the sections that follow.

4.1 Pen-and-Paper Approach

The author has conducted a study to test a pencil-and-paper based constructivist approach to teaching FLAT topics. In traditional teaching methods students are lectured on the FLAT concepts and complete exercises during a tutorial on these concepts. In this case the teaching of the concepts and the testing of the students’ understanding and knowledge (by means of tutorials) obtained during teaching are done in different sessions at different times. The problem with this scenario is that students are not able to immediately test their perception of the concepts taught and obtain immediate feedback to rectify any misconceptions.

In the approach taken by the author the structure of lectures was changed to facilitate students testing their comprehension of the topics taught immediately and receiving immediate feedback to allow them to correct errors in their knowledge and understanding. During a lecture a new topic is firstly introduced. The students are then required to work on exercises which help test their comprehension of the concept. The student can ask for assistance while working through the exercises. The students and lecturer then go through the solutions together. For example, in teaching the construction of automata or grammars the lecturer obtains a complete or partial solution from a student. The lecturer then works through how the students can assess the solution and how to improve the solution if it is incorrect.

The tutorial for the week further tests the students’ skill and knowledge gained during the lectures for the week by presenting students with more challenging problems than those worked through in lectures. It is anticipated that this approach will progressively develop the students’ knowledge of FLAT concepts and skill at solving problems. The tutorials are marked by the lecturer and a tutorial feedback session is held to discuss problems generally experienced by students with the tutorial. These tutorials also give the lecturer an idea of which concepts the students’ have not grasped and which skills need to be further developed.

An evaluation of this approach was conducted. Students were asked to anonymously write down what they liked about the course, what they did not like about the course and any suggestions they may have. The evaluation revealed that students found this approach helpful in learning the different FLAT concepts. The students felt that the approach was interactive and that the exercises during lectures helped them to understand the concepts taught. Some of the comments made by students include: “Interactive, lots of examples”; “The technique of working examples in class for a few minutes and thereafter going through it together, I personally thought was very helpful and effective since it allowed us to grasp the concept quickly and thus making learning easier”; “What is done in lectures is reinforced in tutorials”; “The tutorials were done almost in conjunction with the lesson, so we could extend what we had learnt”.

However, these methods could not be used to help students conceptualise proofs and some students felt that while they had grasped the “mechanics” of proofs they had not developed a deeper understanding. The use of visualization tools, which is discussed below, is a possible solution to this problem.

4.2 Pen-Based Computing Approach

Berque et al. [3] have tested the use of pen-based computing as a means of ensuring that students are “actively engaged” throughout a FLAT lecture. Often students are absorbed in note taking rather than concentrating on explanations being provided by the lecturer. The approach taken by Berque et al. is similar to the pencil-and-paper-based approach described above. The lecturer basically presents new material to the students using the electronic whiteboard. Students do not need to take notes since whatever is written to the whiteboard is automatically transferred to the student video tablets. The students, using pen-based computing tools, can add their own personal explanations and notes to the material and store it. Students are then required to work on a problem on the material, e.g. constructing a DFA, and can obtain assistance from the lecturer
if needed. The lecturer then randomly selects a student’s solution, which is transmitted to the lecturers video tablet and discussed with the class. This process is repeated for each new concept introduced. To encourage students to play an active role in this process students are allocated an “engagement grade” which contributes to their class mark.

An empirical evaluation of this approach revealed that students found this method effective in helping them grasp the different concepts. A majority of the students indicated that they preferred this form of lecturing instead of the traditional chalk-and-board methods. Students also indicated that this form of instruction forced them to be more attentive during lectures.

### 4.3 Visualization Tools

Numerous visualization tools have been developed to motivate students and assist them in understanding FLAT constructs and proofs. These tools facilitate experimentation that would be difficult and boring to do on paper [33]. Some of these tools basically provide animations of the different concepts and proofs. Others allow students to create different FLAT structures like automata and grammars and simulate the created construct and so debug it. These tools can be used in the classroom by lecturers and by students in tutorials and for revision and studying purposes. This section provides an overview of these tools. A majority of these tools are freely available over the Internet.

Chesnevar et al. [6] divide the visualization tools into two categories, namely, those that focus on a single concept or type of language, e.g. finite automata, or the Pumping Lemma, or regular languages, and those that cover more than one FLAT topic, e.g. finite automata and pushdown automata and Turing machines. In this paper these categories will be referred to as single-function and multi-function tools respectively. In some instances the tool has been developed over time and hence a number of different versions of the tool exist. In these cases the latest version of the tool is described.

Single-function tools have been developed for regular expressions, finite automata, pushdown automata and Turing machines. A number of tools exist for visualizing regular language structures. RegeXeX is a tool developed by Brown et al. [4] to help students construct regular expressions. RegeXeX presents the student with an exercise, from the repository of exercises maintained by the system, and provides feedback on the correctness of the solution. RegeXeX can also be used in the classroom to illustrate how regular expressions are created. CAVE (Constructive Algorithm Visualization Environment) is a teaching aid to assist lecturers in constructing the creation of DFAs and combining DFAs using operators such as union and concatenation [6]. FSME (Finite State Machine Explorer) provides an environment in which the user can construct finite state machines and test them on different inputs [6]. It also caters for the conversion between equivalent classes of machines. TAGS (Transducer Automata Graphical Simulator) allows the user to define and run finite state transducers, namely, Moore and Mealy machines [13]. FSA Simulator simulates deterministic and nondeterministic automata by highlighting transitions between states ([15], [16], [17]). The user is able to create DFAs in the form of transition diagrams, FSA Simulator checks the solution entered by the student by determining the equivalence of the student’s DFA and a stored solution and guides the student on how to correct his/her attempt. ProofChecker is used to create, in the form of a transition graph, and visualize deterministic finite automata [36]. ProofChecker provides feedback on solutions entered by students highlighting both the syntactical and semantic errors made. ProofChecker also assists students in determining the language a DFA accepts. Two versions of ProofChecker have been developed, one for sighted students and another for visually impaired students. The authors have also developed ProofGrader for marking student submissions.

Language emulator Vieira et al. [40] and FAdo (Finite Automata devoted oracle) developed by Moreira et al. [27] enable the user to create and simulate regular expressions, regular grammars, deterministic and nondeterministic finite acceptors. The user can also perform operations such as union, interaction, difference and complement on DFAs. These systems also perform conversions of NFAs to DFAs, conversions between finite acceptors and regular expressions, conversions between finite acceptors and regular grammars. Both systems find errors in student solutions and provide feedback on the errors. In the language emulator input is in the form of a transition table while input to FAdo is in text form. The language emulator also allows for the creation, simulation and conversions of Mealy and Moore machines.

IPAA (Interaction Pushdown Automata Animation) is a system developed by McDonald [26] and is dedicated to the creation and simulation of pushdown automata. PDAs are entered as transition graphs and the user is given the option of stepping through simulations. Visual tools for Turing machines include Turing’s World [40], Turing Machine Simulator and VisualTuring [6]. Turing’s World provides an environment in which the user can construct and simulate Turing machines while Turing Machine Simulator and VisualTuring basically simulate existing machines and allow the user to edit the existing machines.

Multi-function visual tools include Minerva, JCT (Java Computability Tool), DEM (Deus ex Machina), AtoCC, jFAST and JFLAP. Minerva can be used to construct and debug finite state acceptors, PDAs, Turing machines and grammars [6]. It also helps students to construct solutions to problems on the Pumping Lemma for regular languages. Unfortunately, Minerva is only available in Spanish. JCT also caters for the creation and simulation of finite automata and Turing machines [6]. DEM is a supplement to a textbook on FLAT [37] and covers finite state machines, pushdown automata, Turing machines, register machines, vector machines, linear-bounded automata and Markov algorithms [6]. Taylor [38] uses DEM to demonstrate the Church-Turing thesis. Taylor states that tools such as DEM allow for different models of computability to be constructed and analysed, thus facilitating such a demonstration.

AtoCC assists students in understanding the phases from creating a finite automaton through to compiler construction [20].

JFLAP (Java Formal Languages and Automata Package) has been developed over a number of years ([5], [14], [30], [31], [32], [33], [39]). It facilitates the construction and simulation of regular expressions, finite acceptors (DFAs and NFAs), finite transducers (Mealy and Moore machines), regular grammars, PDAs, context-free grammars, unrestricted grammars, single and multi-tape Turing machines, L-systems, LL(1) and SLR(1) parsers. JFLAP can perform conversions between automata and grammars for regular and context-free languages, conversions between regular expressions and automata and conversions between Mealy and Moore machines. It also allows for the simplification of context-free grammars and the conversion of CFGs to normal forms. JFLAP can also test the equivalence of machines, minimise DFAs and combine automata. Later versions of JFLAP facilitate the creation of complex Turing machines by combining simpler machines which are treated as...
building blocks. JFLAP also caters for the creation and simulation of Universal Turing machines. The latest version of JFLAP provides games for assisting students in learning the Pumping Lemma for regular and context-free languages.

JFLAP has been used by both students and lecturers. For example, JFLAP can be used in lectures to illustrate the properties of regular languages when proving that regular languages are closed under certain operations or illustrating the advantage of a two-tape Turing machine over a one-tape Turing machine. JFLAP has also been used in a classroom setting where students are firstly required to use JFLAP to either solve a problem or rectify an incorrect solution. The students and lecturer then discuss the different approaches to finding a solution [14]. JFLAP also provides lecturers with a facility for batch marking.

According to White et al. [42] most visual tools for FLAT require students to have some knowledge of concepts and mathematical notation used and are thus not suitable for introductory level FLAT topics such as those typically taught at first year level. White et al. have developed jFAST as a supplement to existing visual tools. This tool can be used as an aid in basic FLAT courses with other tools such as JFLAP being used later on in the curriculum. In the development of jFAST emphasis was placed on ease-of-use and is aimed at providing assistance in both the teaching and learning of FLAT. Users can construct and simulate finite automata and jFAST performs error checking on solutions entered and provides feedback accordingly. The error-checking component can also be used by lecturers to mark student tutorials. jFAST also facilitates the simulation of PDAs and Turing machines.

Hannay [19] has created a package consisting of web-based simulators for regular expressions, finite state machines, pushdown automata, context-free grammars and Turing machines. This package enables students to trace through built-in examples of the different structures and so assists them in conceptualising these constructs.

Wermelinger et al. [41] use a Prolog toolkit rather than a simulator to assist students in learning FLAT concepts. The toolkit contains structures and proofs that can be used and/or extended by students to test and develop their understanding of regular language structures and pushdown automata. The toolkit “reinforces learning by doing”. The authors feel that while simulators provide a visualisation of the different structures, the toolkit facilitates a deeper level of understanding of concepts as the student is required to understand and change existing programs. Thus, the authors suggest that the toolkit be used in conjunction with a simulator.

Student feedback on the use of visual tools was generally positive. According to Vieira et al. [40] students found the tools helpful in testing the solutions they firstly created on paper. Studies with JFLAP revealed that a majority of the students preferred either using JFLAP to create solutions or firstly constructing solutions on paper and then testing it with JFLAP.

It is evident from the discussion presented in this section that there are a variety of tools available to help learners conceptualise the different FLAT concepts. These tools differ with respect to interfaces, input formats and simulation processes. JFLAP has proven to be quite popular and the authors report that it is currently being used in over 160 countries by both students for learning purposes and lecturers for more effective teaching [33]. Empirical evaluations of the different tools have indicated that there is no one best tool [18]. Students’ learning styles have a direct impact on which tool/s they prefer. Furthermore, a number of students preferred to use more than one simulator to give them different views of FLAP concepts [6], [7], [8]). Table 5 below lists the websites for the tools discussed in this section that are accessible via the Internet.

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4.4 Intelligent Tutoring Systems

Intelligent tutoring systems (ITSs) are learning tools that provide the learner with individualised tuition. The ITS maintains a model of the student’s knowledge and skills on the concepts being taught and tailors the instruction accordingly. There is not much research into the use of ITSs for FLAT and most of the work is still in the early stages of development. For example, Pillay et al. [29] describe how genetic programming can be used in the expert module of an ITS for finite automata to automatically generate solutions to problems presented to the student. The generated solutions can then be compared to the student solutions and feedback can be provided accordingly. Devedzic et al. [12] propose an intelligent tutoring system, namely FLUTE (Formal Languages and Automata Environment), to teach FLAT. The architecture of FLUTE consists of an expert module, an explanation module, a student model, a pedagogical module and a user interface.

The expert module consists of domain knowledge obtained from text books and experts in the field and includes information on applications of FLAT, lesson plans for the different topics and a set of examples and exercises. The explanation module generates answers to student questions. The student model keeps track of the student’s knowledge and how the student learns. This model is constantly updated. Based on the student model, the pedagogical module decides on what to teach next, which problems to use to test the student, how much help to give the student and when the student needs this assistance. This module is also responsible for responding to student questions.

The system provides for four learning levels, namely preliminaries, basic, senior level and advanced level. The preliminary level covers mathematic basics needed and the

Table 5: Visual tools that can be accessed via the Internet

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The system provides for four learning levels, namely preliminaries, basic, senior level and advanced level. The preliminary level covers mathematic basics needed and the
definition of a language. Finite automata, pushdown automata, regular grammars, context-free grammars, and the relationship between grammars and automata are taught at the basic level. The senior level focuses on Turing machines and decidability and the advanced level examines closure properties of languages, complexity theory, syntax analysis, grammatical transformations and other language classes. Only the preliminary and basic levels have been implemented at this stage of the development of FLUTE.

Mechanisms are built into FLUTE to motivate students and keep them actively engaged in the learning process. e.g., the system will compliment the student every now again when he or she has created a solution to a problem; when presenting a particular concept the system may give examples of current applications.

Given the success that intelligent tutoring systems have had in other domains, they definitely have potential in assisting learners overcome learning difficulties with FLAT. However, research in this area is still in its infancy and much more work needs to be done on the development and evaluation of these systems before they make their way into Computer Science laboratories.

4.5 Stimulating Student Interest

Students taking FLAT courses tend to feel that these courses are outdated and irrelevant to the rest of the Computer Science curriculum and are thus generally disinterested. Consequently, a fair amount of work has been conducted into methods for stimulating student interest in FLAT topics. The following methods have proven to be effective at rousing student interest in FLAT:

- Using examples to link FLAT to other topics in the Computer Science curriculum – Chesnevar et al. ([7], [8]) suggest that the different FLAT concepts can be illustrated in the context of a particular programming language. Students taking the course would already have knowledge of a first programming language such as Java and would thus be able to relate to the illustrations. Chesnevar et al. show how the properties and limitations of the different types of languages and grammars can be depicted using a programming language. Using current computer applications of FLAT to introduce different FLAT topics - According to Devedzic et al. [12] students’ interest can be increased by showing them where they can apply the knowledge they have obtained, for example in compiler construction or designing adaptive screen forms. Applications cited in the literature as being useful for this purpose include logic programming and formal verification [39]; programming languages, query languages, data description languages such as XML; text searches based on regular expressions and communication protocols [41]; anti-virus problems to illustrate the halting problem, using a finite automaton to model word recognition in a text-entry interface, and hypercomputers [7]. Schreyer et al. [34] illustrate the functioning of a nondeterministic finite automaton by using an NFA to model a critical process with a binary semaphore. A recent article entitled “Things I learned in School” published in “ACM Queue”, explains the crucial role played by finite state machines in user interface design [10].

- Examining the role that FLAT has played in the history of Computer Science – Both Verma [39] and Chesnevar et al. ([7], [8]) have found that placing FLAT in context of Computer Science history makes the course more interesting. For example, when teaching Turing machines Chesnevar et al. link this to the history of Alan Turing’s life. When introducing the Church-Turing thesis Chesnevar et al. comment on the fact that both Alan Turing and Stephen Kleene were PhD students of Alonzo Church and thus had similar research goals. Verma has included links to historical information on the course webpage.

- Using games to illustrate different FLAT concepts – Olagunju et al. [28] use the click game to introduce the concept of a finite state machine. A finite automaton is used to model the wins and losses in the game. A different approach is taken by Korte et al. [23] in which students use different automata to build their own game. These games are generally of a social nature and can differ for different countries and cultures. For example, one of the games built in the study conducted by Korte et al. is “Becoming the Leader of the Conservative Party” and was developed during elections for a new British conservative party leader. Korte et al. show how game-building can be used to help students obtain an understanding of finite automata and Turing machines. An empirical evaluation of this approach revealed that while game-building most definitely motivated weaker students it had a negative effect on stronger students. This once again emphasises that in teaching FLAT topics more than one strategy should be used to cater for the different learning styles of students.

5. DIRECTIONS FOR FUTURE RESEARCH

From the above discussion it is evident that there has been much research conducted into improving the teaching and learning of FLAT courses. This section proposes future directions for this research.

By taking a similar approach to that used by Wermelinger [41] in developing the Prolog toolkit, the fact that “computer science students generally enjoy writing computer programs” [42] can be used to help students better conceptualise and understand FLAT topics. In writing a program for a particular application, one usually obtains a better understanding of this domain. Students enrolled for FLAT courses in their third year of study would have already been exposed to one or more programming languages and data structures. An area for further investigation would be to test the effect of getting students to write programs that construct and simulate particular automata and grammars. Interface libraries can be provided to ensure that students focus on FLAT concepts only. Students can also write programs that perform conversions from one structure to another, e.g., grammars to automata and vice versa. In learning the Pumping Lemma for regular languages students can write a program that determines the necessary partitions for words into x, y, and z [25].

Chesnevar et al. [7] state that students often develop incorrect mental models of FLAT topics. Research shows that intelligent tutoring systems provide the necessary individualised tuition necessary to help students develop the correct mental models of different concepts. However, not much work has been done on the use of intelligent tutoring systems for teaching FLAT courses and the development of such systems are still in their initial stages. More research into the building of such systems needs to be conducted so as to speed up the process of getting these systems into laboratories for student use. The effectiveness of using collaborative learning by means of group work as a teaching tool for Computer Science is
highlighted by Beck et al. [2] and Joseph et al. [22]. Beck et al. state that in addition to aiding the learning process, collaborative learning also improves students’ attitudes towards the course. There has not been any research into the use of collaborative learning in FLAT courses to stimulate interest and assist students in overcoming learning difficulties. This needs to be investigated further.

It is clear from the discussions presented in this paper that there has been a large amount of research into strategies, such as the use of visual tools, for improving both the learning and teaching of FLAT topics. However, evaluations of these methodologies have generally been of an empirical nature. Instruments for evaluating these strategies need to be identified and a more concrete assessment of the benefits of these methods for teaching and learning needs to be conducted.

6. CONCLUSION

This paper reports on teaching formal languages and automata theory (FLAT) as part of the undergraduate Computer Science curriculum. It provides an overview of how formal languages and automata theory can be integrated into a CS undergraduate curriculum. It also highlights the teaching and learning difficulties associated with FLAT courses and suggests strategies for overcoming these problems. It is evident that traditional chalk-and-board methods are not effective in the teaching of FLAT and constructivist teaching strategies that promote active learning are essential for students to obtain a deeper understanding of FLAT topics. This study has revealed that a combination of teaching strategies is needed in teaching FLAT courses in order to cater for the different student learning styles. The paper has also identified areas that need to be investigated to further improve the teaching and learning of FLAT.

REFERENCES


CS, IS, History, and the Unity of Science

Stefan Gruner
Department of Computer Science, University of Pretoria, Lynnwood Road, 0002 Pretoria

ABSTRACT
This letter is a reply to SACJ 40 Editorial entitled “It is time for IS to understand its history”.

1. The purpose of science is to describe and explain observable phenomena, regardless of whether their objects have been artificially created (engineering, mathematics, studies of literature and fine arts) or whether they have been discovered in our environment without being purposefully created (natural sciences, medicine, ethnology). There are other semiotic and hermeneutic systems, such as philosophy and theology, which also try to explain or give meaning to historic facts or observable phenomena; from them we distinguish science methodologically by constraining what phenomena shall be admitted for investigation and how the investigation has to be carried out.

2. There are not many sciences (in plural); there is only science (in singular), though obviously in a variety of different forms and traditions represented by the variety of academic faculties. All science, however, is characterised by the general applicability of Popper's falsification criterion. Other semiotic or hermeneutic systems, to which Popper's falsification criterion is not applicable, do not fall under the category of science; they fall under the categories of philosophy or theology (which does not mean that they would not have any value in human life). The mere construction of artifacts, without any form of theoretical explanation attached, is also not science; this is technics or craftsmanship (which also does not mean that this would not have any value in human life). Last but not least in this section: the question of what possible scientific study to undertake and what scientific study not to undertake (e.g. for the greater benefits of society) is a question of politics, not a question of science itself; physics itself cannot tell us if physics is “good”, and the same is true for any other science.

3. Since the publication of Kuhn's influential book, the word "paradigm" has been stretched by various people and groups like a rubber ribbon, to suit their theoretical or ideological needs, to such an extent that Kuhn's originally intended meaning of the term can hardly be recognized in those variations any more. “Paradigm” has become an almost meaningless commodity word in these days. The Kuhnian idea of radical incommensurability between two historically competing paradigms has been forgotten by and large.

4. One cannot simply invent or come up with a new paradigm (in the strict Kuhnian sense of the word) in a voluntary act. Kuhn has clearly emphasized (in an almost Hegelian spirit) that an old paradigm must have utterly failed before a new one can emerge. “Failure” of a paradigm, however, means: Inability to explain a substantial amount of “new” (or hitherto unknown) phenomena - recall what has been said above about science as an explanatory undertaking - in a situation of scientific “crisis”.

5. With respect to the so-called “paradigm wars” - i.e. “crisis” in strict Kuhnian terminology - which the esteemed editor of this journal has mentioned in his SACJ 40 editorial, I would like to learn from leading representatives of the IS community: What are the new phenomena which their old paradigm is allegedly not able to explain any longer? Which observable objects are the stumbling blocks of their old paradigm? My impression, from an outsider's perspective, is that the IS “paradigm war”, as described in the above-mentioned editorial, does not seem to be related to observable phenomena and real-world objects at all; it appears to me as a purely scholastic and metaphysical debate.

6. From the observation of a methodological quarrel, fought out by followers of competing schools of thought in a particular discipline, one should not easily jump to the conclusion that one is actually observing a science in crisis, at the edge of a Kuhnian paradigm shift. Thinking in Kuhnian lines, such an observation could also mean that the quarreling discipline is still very young and yet in a pre-scientific state, before it’s very first paradigm has been firmly established at all. One has to remember that Kuhn, with his “paradigm shifts”, was writing from a distant perspective about several centuries of (astro) physics, not about a discipline that has just hatched out of its egg.

7. Computer scientists do not need any special invitations for “beginning to reflect” upon the history of their discipline - in fact they are doing this all the time, and there are many books and entire conferences dedicated to this theme. We are fully aware of the profound impacts which our discipline, CS, in close cooperation with our sister disciplines, electronics and discrete mathematics, has had - and continues to have - on the world so far. We know today that what we now call a “von-Neumann Architecture” had already been built by Konrad Zuse several years before von Neumann; we know that we could not automatically generate a compiler without Noam Chomsky's hierarchy of grammars; we know that we could not have built any CD drive without Claude Shannon's channel coding theorem, etc.; and - last but not least - this

1 Email: sg@cs.up.ac.za
year 2008 has witnessed an amazing amount of historical reflections at the occasion of the 40th anniversary of the 1968 NATO Science Conference in Garmisch, at which Software Engineering as a discipline was born. Computer Science has rocked the world with amazing results, and we are fully aware of this.

8. However, great care must be taken that we do not fall into the trap of the dilettantism of amateur historianism. Though it is not uncommon for professors emeriti of all faculties to sit down and write “A History of” their discipline in their quiet hours of retirement, we should not too easily believe that every good medical doctor would automatically make a good historian of medicine; likewise not every good engineer would also be a good historian of technics and technology. History is a discipline in its own right, with its own intellectual tools and methodological techniques, which have to be thoroughly studied before they can be properly applied. A significant and reliable “History of Computer Science”, so I conjecture, could only be written in close cooperation of historically informed computer scientists together with technologically informed historians - not by any of those types of people on their own.

9. Finally, some healthy skepticism against history itself seems appropriate, too. Is it really possible that - as it is often claimed - we are able to “learn from history”? Has all the knowledge of WW1 prevented WW2, and has all the knowledge of the Korea War prevented the Vietnam War? To what extent is it useful and to what extent is it counter-productive to spend our time on historical studies? What does my historical knowledge about Konrad Zuse’s electro-mechanical flip-flop apparatus tell me about my broadband connection to the internet? Here I do not need to argue any further; it suffices to remind the reader of Friedrich Nietzsche’s famous essay *Vom Nutzen und Nachtheil der Historie für das Leben*. 
Notes for Contributors

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The South African Computer Journal is an accredited specialist IT academic journal, publishing research articles, technical reports and communications in English in the Computer Science and Information Systems domains. While it is intended primarily as a local forum for research publications, contributions from scholars from other countries are most welcome to submit articles for review. All research articles and technical reports submitted for publication are rigourously refereed by independent peer reviewers, ensuring that the journal publishes original work that is of international stature. The editorial board comprises local and international scholars of high repute. The journal, which appears approximately twice per year, is accessible through the SABINET portal at the address given in the header of this page.

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  - the author’s initials and surname
  - the author’s affiliation and address
  - an abstract of less than 200 words
  - an appropriate keyword list

- Tables and figures should be numbered and titled.

- References should be listed at the end of the text in alphabetic order of the (first) author’s surname, and should be cited numerically.

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http://blues.sabinet.co.za/comp/ which gives a number of examples.

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