Toward teaching methods that develop learning and enhance problem solving skills in engineering students

K. Loji
Department of Electrical Power Engineering
Durban University of Technology
Durban, South Africa,
E-mail: kabulol@dut.ac.za

Abstract

Problem solving skills and abilities are critical in life and more specifically in the engineering field. Unfortunately, significant numbers of South African students who are accessing higher education lack problem solving skills and this results in poor academic performance jeopardizing their progress especially from first to second year. On the other hand, teaching problem solving to under-prepared first year learners is a challenge to academics that are required to think in innovative ways about teaching and learning strategies in order to respond in an efficient manner to South Africa’s high demand for quality engineering graduates.

This article discusses two successful sample lessons of how higher-order thinking skills can be integrated into the content of a so called ‘bottle-neck’ subject namely Electrical Engineering 1 (EE1) with the goal of enhancing problem solving skills and consequently improve under-prepared learners’ performance. The importance of developing active student engagement practice as well as conceptual understanding is highlighted.

INTRODUCTION

The field of engineering requires development of problem solving skills during the time of study and as practising engineers. Jansen (2007) notes that these skills are particularly lacking in learners accessing universities with the aim of studying engineering. To date, many causes have been investigated and one of the deficiencies is the school-university gap that is due to the under-preparedness of learners accessing tertiary education. Efforts to address this deficiency include the implementation of Foundation or Extended Curriculum Programmes (ECP) that some Universities and Universities of Technology are currently experimenting with. While a fair amount of interventions have been dedicated to address learning issues where the focus is on the learner, not much has been done to address different teaching strategies. In fact, a number of engineering educators, who were appointed on the basis of their own academic performance in their respective fields of expertise, are under-prepared for teaching. This might be contributing to the learners’ under performance since they do not receive enough support from the educator. Reif (2008) argues that ‘some experts
become so familiar with the knowledge in their field that they use it spontaneously without deliberate thought. This knowledge used without conscious awareness can make it difficult for experts to transmit information to others with the result that proficient performers may sometimes be poor teachers.’

Also, indications strongly support a shift in teaching from just a ritualistic presentation of ‘facts’ or ‘concepts’, to teaching that encourages learners’ active involvement in their own learning. This work predominantly focuses on the cognitive aspect of education and the following crucial questions (Reif 2008) were helpful in exploring and supporting the shift:

1. What kind of knowledge and thought processes are needed for (students’) good performance?
2. What are some difficulties faced by students, used to everyday thinking, when they need to deal with scientific domains?
3. What instructional methods can help students to learn the kind of knowledge and thinking skills required in such domains?
4. How can such methods be implemented to provide practical instruction for many diverse students?

In the following sections of the article, I discuss how I have integrated higher-order thinking skills in the subject content combined with other strategies, approaches and practices to improve the understanding of basic concepts that prepare and equip engineering learners for problem solving skills. The intervention firstly benefited ECP learners in 2009 and later in 2010 learners in the mainstream this time. Two sample lessons successfully conducted in that regard are presented and comparative analysis of students’ performance provided.

CONCEPTUAL FRAMEWORK: NEED FOR COGNITIVE STRUCTURES

Problem solving requires synthesis, analysis and evaluation which are rated on the Bloom’s taxonomy scale as the three higher levels of thinking as shown in Figure 1(a) (Miller, Imrie and Cox 1998). This is supported by Lumsdaine et al. (1999) among others who note that creative problem solving process involves all three types of thinking: analytical, creative and critical. This is challenging for engineering learners in general and particularly for under-prepared learners accessing engineering programs in South Africa.
As also noted by Naudé and Westhuizen (1996) and Miller et al. (1998), observations carried out with learners inform that in any kind of assessment, learners are very good at remembering and repeating material from lecture notes and textbooks but unable to solve problems which they have not previously seen or discussed. This may be due to the fact that the teaching arena is still dominated by the pedagogy based on old teaching methodologies that are characterized by deductive teaching approach (Sheppard et al. 2009) in which ‘the professor stands at the front of the room, copying a derivation from his notes onto the board and repeating aloud what he writes’ (Felder et al. 2000) while learners are attentively taking notes. It is unlikely that under-prepared learners will benefit from this as many beginning engineering students are still in formative stage of cognitive development (Sheppard et al. 2009) and therefore need adequate guidance in developing reflective thinking: the highest stage of cognitive development (King and Kitchener as cited in Sheppard et al. 2009) in order to problem-solve in a variety of situations.

High-order thinking skills in engineering students need to be developed as early as possible (Eggen and Kauchak 1996) to enhance their problem solving skills and discovery of new knowledge (Lau 2004) which consequently better prepares and equips them for professional challenges in their fields. To achieve this cognitive change and reach the ultimate goal of teaching for reflective learning, it is imperative that teachers transform their way of facilitating learning.

**THINKING SKILLS AND LEARNING IN THE FIELD OF ENGINEERING**

Anecdotal work from 2007 with a number of learners revealed various deficiencies and potential causes of failure. The three major causes identified were: poor reasoning abilities, lack of self-commitment or independence in the learning process and lack of self-confidence. Poor reasoning ability is the result of lack of thinking skills. In
fact, learners encounter difficulties in taking correct actions and steps while solving problems of various kinds especially if qualitative questions are posed. Given below are examples of typical questions that learners fail to attempt because either there is no need for the straight application of formulae or no numerical set of data were provided:

**Question 1**
Consider two bulbs of the same power P connected in parallel across a source V and giving certain brightness. You connect a third bulb of the same power P in series with the first two (still connected in parallel) and you double the source voltage. What will happen to the brightness of the first bulbs, will it increase, decrease or remain the same? Substantiate your answer.

**Question 2**
What angle do the minute and hour needles of a watch make when the time is 26 past 2?

**Question 3**
In the circuit diagram given in Figure 1(b), if all the resistors are equal to $R_1$, Show that the equivalent resistance measured between terminals A and B ($R_{AB}$) is equal to $\frac{5}{6}R_1$

![Figure 1(b): Circuit diagram for sample question 3](image)

Learners are affected by the lack of basic reasoning principles (beside formulae) to support their reasoning, reinforce their confidence and validate the process toward the solution. As a result, during assessments, they write to fill in the answer sheet or they don’t attempt questions at all.

The issue regarding improving engineering learners thinking skills is an ongoing one in various fields of engineering education worldwide. Redish and Smith
K. Loji

(2008), Felder, Rugacia, Stice and Woods (2000), and Sheppard et al. (2009) along with others stress the importance of thinking about thinking: that ‘metacognitive’ approach to instruction which helps learners to take control of their own learning by defining learning goals and monitoring their progress in achieving them. One of the big questions is whether thinking skills should be taught as a separate subject or integrated into the content syllabus of the subject. Perkins (as cited by Eggen and Kauchak 1996) claims that: ‘learning is a consequence of thinking’ and suggests that thinking and knowledge of content be taught at the same time. This is the approach that was used in designing and implementing the intervention.

**Problem solving and cognitive education**

At the beginning of the engineering studies, ‘problems’ are presented as engineering concepts or subject matter based. As the learner progresses, broad based ill-defined problems or multidisciplinary design kind of problems are gradually introduced. It must be noted that interventions with first year learners were mostly addressing concept based problems along with integrating thinking skills components throughout various activities to motivate learners to engage in their own learning and discourage passive learning.

To claim that learning had occurred suggests that learning must be assessed. According to Rief (2008), learning is assessed by the positive change in performance between the initial performance $P_i$ (what the learner is capable of accomplishing prior to the learning session) and the final performance $P_f$ (what the learner can accomplish after the learning). The assessment of initial performance $P_i$ helps identify deficiencies and misconceptions in the learners and guide the instructor in the manner and the level at which the new lesson should be designed and conducted. In our intervention, the above assessment was systematically done by giving a non-graded pre-assessment to determine the students’ level of preparation (prior knowledge) related to the concept being taught that day. At the subsequent lesson, an assessment on the previous lesson was done determine the final performance hence evaluation learning.

**DESCRIPTION OF THE INNOVATION**

**Teaching methodology**

The deductive method of teaching engineering concepts and principles, shown in Figure 2(a), is the most dominant method as noted by Sheppard et al. (2009). In this method, lectures are illustrated by interrogations and blackboard demonstrations. It is preferred because of among other reasons, it responds to the challenge of large classes and to the pressure of covering course content in limited time. However, deductive teaching method is not learner centred and does not encourage learners’ active involvement in their own learning. Figure 2(a) displays the ‘professor’s’ role of the instructor and the ‘passive’ role of the student.
As suggested by Sheppard et al. (2009) the inductive teaching approach shown in Figure 2(b) was the instructional delivery method that was preferred to conduct teaching in our intervention. Lessons, as it will be seen in the sample lessons, were structured to include the following basic processes of thinking: *Observing* – *Finding patterns and generalizing* – *Forming conclusions based on patterns* – *Assessing conclusions based on evidences* (Eggen and Kauchak 1996). It can be argued that this instructional delivery method has the potential to actively engage the learner in the learning process.
Teaching concepts through cognitive structures

Sheppard et al. (2009) suggest that students learn with understanding when they have the opportunity to develop a conceptual framework for the facts so that they are not trying to store them as disconnected pieces of information. This is supported by Eggen and Kauchak (1996) who consider cognitive structures as conceptual frameworks by noting that ‘one way of viewing the information we have stored in our memories is to think to it as an organised and interconnected network of ideas often called a conceptual framework’.

In addition to the conceptual framework, Eggen and Kauchak (1996) suggest the use of cognitive structures as ‘schemas’ which describe knowledge as dynamic and useful sets of interconnected ideas, relationships, and procedures. They consider that ‘Schemas, not only organize information and tell us what to expect from the world; they also tell us how to operate within it’. Beside ‘Conceptual framework’ and ‘Schemas’, Lumsdaine et al. (1999) suggest the use of mindset metaphors. As demonstrated through the sample lessons below, conceptual framework, schemas and mindset metaphors were extensively used during class activities.

In the following paragraphs, two examples of lessons are given where thinking skills are integrated into the subject content to get the learners to overcome the threshold difficulties of learning all new (in a sense that we assume they were not properly taught before), abstract and confusing concepts.

SAMPLE LESSON 1: VOLTAGE, RESISTANCE AND CURRENT CONCEPTS AND THE RELATIONSHIP BETWEEN THEM

Voltage, Current and Resistance are threshold concepts in the engineering field in general and in the Electrical Engineering sub disciplines (Electrical Power, Electronic, Computer Systems, Mechatronic, etc.) in particular. A better understanding of these concepts individually as well as the relationship between them (Ohm’s Law) is critical in succeeding in engineering studies. With the deductive approach of teaching as described above, these concepts are introduced by presenting a lecture on atomic structure of the matter followed by electrical charges, and thereafter voltage, resistance and current are taught one after the other in a separate and disconnected manner (Floyd 2010). At this level of study, these concepts are so ‘abstract’ and ‘meaningless’ for many underprepared first year learners that they are learnt with lots of misconceptions. When assessed using qualitative type of questions, learners’ performance is minimal and limited to answering the question ‘what?’. Learners can define each concept individually but are unable to clearly establish and explain the interdependence between the three concepts. The following lesson was presented in the laboratory to 86 students and the methodology described above was followed.

Step 1: Observation, finding patterns and generalizing

Initial performance was first assessed and more than 80 per cent of the learners demonstrated prior rote learning and confusion regarding the concepts. Halloun and
Hestenes (as cited in Reif 2008) noticed that when learning did not happen, learners emerged with significant misconceptions and with fragmented knowledge that they could not reliably use.

Learners were then taken to the laboratory to observe electrical phenomenon through experimentation. From the experiments it was expected that learners would find patterns and extract the fundamental concepts and their respective meaning. Equipment were marked with alphabet or letters to facilitate the process, but also to minimize the importance of the ‘name’ over the ‘function’ of the equipment as a car driver will necessary not need to know the name of the car parts (gear lever, steering wheel, accelerator, etc.) to drive the car.

Equipment used: Voltage supply (A), leads (B), 3 resistors of different values (C, D and E), a bulb (F), a voltmeter (G), an ammeter (H) and a switch (I).

Under supervision and guidance of the instructor, the following was performed in pairs by the learners and answers to questions were recorded progressively:

i) Set (A) to the reading of zero, use (G) to take the output measurement and record the reading.

ii) Turn the knob of (A) marked voltage to a certain value and using (G) measure that output of (A) and note the value. Compare the reading of (G) to the display of (A),

iii) Turn the knob of (A) to zero and watch the reading of (G). What can you say?

iv) Now connect equipment (F) to the output of (A), with (A) displaying zero. What is it happening? Increase the reading on (A) and explain what happened with (F)

v) Remove one side of (F) from (A), what happened? Reconnect it and explain what happened. What will happen if you remove the other side of (F)? What happens if you swap over the 2 connections of (F) to (A).

vi) Progressively decrease the reading on (A) with (F) still connected to (A), explain what you notice

vii) Insert (H) as indicated in the diagram (provided) what do you notice? Increase the reading of (A) in 2 Volts increments up to 12 Volts. What is happening on (F) and on (H)

Space does not allow the display of all the questions as they come to support the learning process. More questions are unfolding as learners build up their observational skills through action.

It must be noted that at this stage:

1. Learners are not yet familiar with the equipment. The teacher’s role is to guide them in their attempt to follow instructions carefully and precisely to reach the predicted outcome (Sheppard et al. 2009). The first demonstrations are controlled or assisted experiments and once learners make progress in operating equipment, the lessons tend to be open-ended experiments where the instructor’s role is minimal in manipulating equipment and limited to set goals, organize and generate problems.
2. Before starting the lesson, learners are told that from the experiment, any other examples or study case (for lessons that are not practical or logistic does not allow practical experimentation), their task is to look for patterns and differences (Eggen and Kauchak 1996) as these would be used to establish some relationship between physical quantities to solve problems (Eggen and Kauchak 1996) or whatever the case may be.

3. Learners are encouraged to refer to concepts or physical quantities using conceptual framework. The teacher should also bear in mind that confusions between the equipment (actual physical component; e.g. bulb) and the physical quantity (e.g. resistance) and the observed phenomenon (light) will be manifest in the process of finding the patterns.

Finding patterns and generalizing

The process of finding patterns was simplified by completing Table 1.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Phenomenon</th>
<th>Role and function of the equipment</th>
<th>What other equipment you know in life which can be compared to and/or associated with</th>
<th>Physical quantity (electrical) associated with</th>
<th>Other comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Expected patterns to be found and focused on are: (1) voltage source (power supply) is the cause of the effects, (2) resistance (resistor) is the object (passive) and electric current is the consequence of the ‘link’ between the two, (3) to produce certain effects (light, heat in a resistor ... later on magnetic effect in a coil); (4) voltage and resistance can exist as standalone physical quantities but current cannot exist if voltage and resistance are not connected.

Step 2: Forming conclusions based on patterns and evaluating conclusions based on evidences

Learners were engaged in discussions from the findings in order to form conclusions based on the identified patterns. Emphasis was put on clarifying the concepts, dissociating physical component (equipment or device) from physical quantity (measured value) and establishing the relationship between various concepts learned. Reif refers to this as specific discrimination tasks whereby learners are helped to detect, diagnose, and correct likely confusions between somewhat similar concepts (Reif 2008). Ohm’s Law was ‘discovered’ by the learners, stated in the learners’ own words and verified through other scenarios for confirmation.
Toward teaching methods that develop learning and enhance problem solving skills in engineering students

**SAMPLE LESSON 2: CAPACITOR: CHARGING AND DISCHARGING PROCESS**

The capacitor is one of the three major components used in the engineering field beside the resistor and the inductor. The goal of this lesson was to help the learner to understand the electrical behaviour of a component which is completely different from the resistor (resistance) and which learners had been familiar with for a few weeks. Basic laws as applied to a resistance had been understood and applied in various applications. Introducing capacitor (physical component) and capacitance (the electrical behaviour associated with) at this stage has the advantage of using what has already been learnt to state differences and/or similarities between the two: capacitor/capacitance and resistor/resistance. However, learners are often confused and struggle when applying similar reasoning to two components that are different in essence.

The deductive way of teaching is to present a definition of a capacitor, generally considered as a passive electrical component that stores electrical charge and has the property of capacitance (Floyd 2010), then describe the capacitor, and finally explain the charging process before producing formulas linking various physical quantities related to the capacitor (capacitance, charge, etc.).

Using the inductive teaching approach, the following lesson was conducted in a classroom (could be anywhere) and the metaphor used is shown in Figure 3(a).

The problem
A classroom has a limited capacity of 72 seats (could be any number) and a large entrance as shown in Figure 3(a). An unlimited number of students are waiting to access the classroom but are separated from the entrance by a large open trench.
(deep hole) that they cannot cross unless a bridge is put over. All students wanted to attend the class.

**Activity 1: Brainstorming and finding patterns**

i) The bridge which was initially removed is placed over the hole to allow access: Explain in your own words what is likely to happen and what you would consequently advise,

ii) If the room is full to capacity, that is 72 seats, what will happen if the bridge is removed? (a) for the 72 students in the room and (b) for the other students left outside;

iii) If the bridge is replaced, are the students in the room able to move out? If ‘yes’ how? If ‘no’, what can be done to help them to move out?

From these questions, discussion followed and the following facts were extracted:

i) Once the bridge is placed, everyone will want to access resulting in a disastrous collision. To avoid this a wall with a door should be built on the entrance (previously empty space) in order to control the flux of students accessing the room. The first flow of students will be huge and will progressively slow down since seats is being occupied.

ii) If the bridge is removed, the students in the room will be trapped inside and the large number outside will stay there waiting for an opportunity to get access once the bridge is replaced.

iii) Although the bridge can be replaced, the students outside will not be able to move in and the ones trapped inside will not be able to move out. To allow the students inside to move out, an alternate door must be installed (back door) while the bridge remains removed or the front door locked otherwise other students outside will access in place of the ones that are moving out.

**Activity 2: From metaphor to real application: drawing analogies and refining concepts**

Through discussions, similarities are established between the classroom metaphor and the electric circuit in Figure 3(b) which describes the principle of operation of a capacitor.

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![Figure 3(b): Charging and discharging circuits of a capacitor](image-url)
i) The room with 72 students is comparable to the plate of the capacitor, and the capacity or size of the room is analogous to the capacitance of the capacitor.

ii) The students in the example are similar to electrical charges and their number/movement is analogous to the charging current.

iii) The bridge represents the switch and plays no active role except from allowing the learners to get into the room, like the switch does, it only allows current flow.

iv) The first flow of students into the room is huge and only controlled by the size of the door. The flow will slow down as the room progressively gets full. This explains the logarithmic shapes of the charging voltage and current as described by equations (2) and (3) below:

\[
\begin{align*}
    i_c &= I_{initial(max)}e^{-\frac{t}{RC}} \\
    v_c &= E(1-e^{-\frac{t}{RC}})
\end{align*}
\]  

... (eq. 2) 
... (eq. 3)

The door is analogous to the resistance in series with the capacitor, the smaller the door the greater the resistance. If the door is closed, this is comparable to a resistance of value infinity or open circuit. The smaller the door (high resistance R), the longer it will take for the room to get full and vice-versa. Also the bigger room (large capacitance C) the longer it will take to get full. This explains the concepts of time constant \( \tau \) and total charging time (approximately \( 5\tau \))

\[
\tau = R.C
\]  

... (eq. 4)

From the above, since the door is similar to the resistor (resistance) it can be understood that if there is no door (no resistance); the disastrous collision mentioned is comparable to a short circuit in the capacitor’s circuit.

\( R_2 \) (and \( S_2 \)) in Figure 3(c) are analogous to the alternative door for the learners to move out and form part of the discharging process of the capacitor.

The learners are thereafter given tasks to theorise on other capacitor’s aspects such as the construction, types, circuits’ connection, applications and depending on the dynamics of the class and the challenges, sample numerical examples can be provided to help learners reinforce the understanding of the concepts being taught.
DISCUSSION

Performance analysis on ECP (2009)

In 2009, ECP students (Heavy Current, Light Current, Computer Systems, Mechanical and Industrial) participated over twelve months (extended program) while mainstream students participated over six months (normal university semester). Final exam results were used as the overall performance indicator and the analysis was based on candidates that were admitted to write the final exam. The ECP was offered to 86 all newly admitted students during 2009 and 72 per cent of them (62 out of 86) successfully completed the course and took the final exam. The overall pass rate in the subject was 69 per cent (43 out of 62) which was significantly higher than the ECP pass rates in 2007 and 2008 which were 18 per cent and 32 per cent respectively, reflecting the ongoing refinement of Electrical Engineering 1 as a subject in the ECP. Heavy Current, Light Current and Computer Systems were attending as one group and, Mechanical and Industrial learners formed another group. Table 2 shows results comparisons between them.

Table 2: ECP summary of 2009 results

<table>
<thead>
<tr>
<th>Engineering Field (Qualification)</th>
<th>Registered</th>
<th>Final Exam</th>
<th>Passed</th>
<th>Exam Marks (Average)</th>
<th>Highest-Lowest (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Power</td>
<td>10</td>
<td>9</td>
<td>78% (n=7)</td>
<td>85% - 33% (61%)</td>
<td>77% - 36% (59%)</td>
</tr>
<tr>
<td>Electronic</td>
<td>20</td>
<td>12</td>
<td>50% (n=6)</td>
<td>70% - 20% (49%)</td>
<td>69% - 33% (50%)</td>
</tr>
<tr>
<td>Computer Systems</td>
<td>11</td>
<td>7</td>
<td>71% (n=5)</td>
<td>62% - 48% (54%)</td>
<td>61% - 46% (54%)</td>
</tr>
<tr>
<td>Mechanical</td>
<td>20</td>
<td>16</td>
<td>75% (n=12)</td>
<td>93% - 28% (61%)</td>
<td>85% - 33% (59%)</td>
</tr>
<tr>
<td>Industrial</td>
<td>25</td>
<td>18</td>
<td>61% (n=13)</td>
<td>88% - 35% (50%)</td>
<td>81% - 38% (52%)</td>
</tr>
<tr>
<td>Total</td>
<td>86</td>
<td>62</td>
<td>69% (n=43)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparison between ECP (n = 86) and Main Stream (n = 347; 3 lecturers) during the same year (2009)

It must be noted that EE1 students in both ECP and mainstream were subjected to the same tests, assignments and exam throughout their program of study. More than 60 per cent of the mainstream learners were repeating the subject along with ECP repeaters from 2008. Three lecturers were in charge of the 347 mainstream students whose performance is compared in Table 3 to the 86 ECP students’ performance. Figure 4 indicates the interpretation graph of the results displayed in Table 3.
Toward teaching methods that develop learning and enhance problem solving skills in engineering students

Table 3: Comparison results 2009: ECP vs. mainstream

<table>
<thead>
<tr>
<th>Engineering Field</th>
<th>Registered ECP</th>
<th>Took Final Exam ECP</th>
<th>Passed (%)</th>
<th>Lecturers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MS</td>
<td>ECP</td>
<td>MS</td>
<td>ECP</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>10</td>
<td>91</td>
<td>9</td>
<td>83</td>
</tr>
<tr>
<td>Electronic</td>
<td>20</td>
<td>141</td>
<td>12</td>
<td>101</td>
</tr>
<tr>
<td>Computer Syst</td>
<td>11</td>
<td>56</td>
<td>7</td>
<td>42</td>
</tr>
<tr>
<td>Mechanical</td>
<td>20</td>
<td>59</td>
<td>16</td>
<td>53</td>
</tr>
<tr>
<td>Industrial</td>
<td>25</td>
<td>0</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>86</td>
<td>347</td>
<td>62</td>
<td>279</td>
</tr>
</tbody>
</table>

Figure 4: Pass rate comparison

As it can be seen from Table 3 and Figure 4, the overall pass rate was higher for the ECP students compared to the mainstream students (69% compared to 42%). In individual engineering fields, all parameters which are essential in the learner’s progress (pass rate, class averages) are in favour of the ECP learners.

Interventions on one main stream group (2010)

In 2010, many of the ECP interventions were used with one mainstream group of 101 students from Industrial Engineering. Because of the reduced time and limited numbers that could be accommodated at once in the laboratory, logistic issues arose
and the implementation of all interventions was challenged. However, results as displayed in Table 4 show once again better performance of Industrial learners who benefited from the interventions compared to the other mainstream groups (Heavy Current, Light Current, Computer Systems) except Mechanical Engineering learners.

Table 4: 2010 results all mainstream

<table>
<thead>
<tr>
<th>Engineering Field</th>
<th>Registered</th>
<th>Took Final Exam</th>
<th>Passed (%)</th>
<th>Lecturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Power</td>
<td>123</td>
<td>63</td>
<td>51% (n = 32)</td>
<td>Lecturer 1 &amp; 2</td>
</tr>
<tr>
<td>Electronic</td>
<td>176</td>
<td>92</td>
<td>52% (n = 48)</td>
<td>Lecturer 2 &amp; 3</td>
</tr>
<tr>
<td>Computer Systems</td>
<td>82</td>
<td>60</td>
<td>43% (n = 26)</td>
<td>Lecturer 4</td>
</tr>
<tr>
<td>Mechanical</td>
<td>66</td>
<td>51</td>
<td>77% (n = 39)</td>
<td>Lecturer 1</td>
</tr>
<tr>
<td>Industrial</td>
<td>101</td>
<td>58</td>
<td>70% (n = 41)</td>
<td>Author</td>
</tr>
</tbody>
</table>

Students’ comments

A survey was conducted among Industrial Engineering learners in 2010. Eighty-five per cent (86 out of 101) responded to the survey providing feedback on the interventions they had received. Only comments pertaining to topics directly impacting on students’ performance in relation to learning and problem solving are discussed.

Learners were requested to use a rating scale from 5 to 1 to respond to questions. To the question about the most challenging thing when engaging in the learning of the subject, 67 per cent of the respondents pointed out the difficulty of understanding key concepts of the subject above all. Concerning teaching and learning methods that contributed the most to their success, 71 per cent of the respondents noted that attending classes was very beneficial for them especially when the class is a hands-on demonstration one. This may be interpreted as a success in facilitation of learning and student/faculty engagement. Positive comments (65%) strongly supported the inductive mode of delivery which the learners refer to as presenting questions and discussing answers.

Impact on the lecturer, identified areas of improvement and way forward

Implementing ECP interventions was very transformative but faculty role development is an ‘ongoing process’, one of continuous learning and experimentation. Overarching issues can hinder implementation of innovative strategies such as the need for large or mass lectures to generate student fees and accommodating the need to prepare quality engineers for South Africa. Cost/benefit analysis studies will be needed to carefully determine if the more interactive, reflective teaching strategies are actually more cost-effective and whether they promote student self-confidence and increase overall success in the engineering workplace.
CONCLUSION

In the Engineering field, problem-solving is fundamental and requires thinking skills. It is imperative that these skills be embedded in the curriculum and taught as part of the subject content for all subjects.

This article showcased how higher-order thinking skills were integrated in the subject content of EE1 with the goal of teaching for knowledge retention and improving learners’ performance. Two sample lessons were displayed to demonstrate that and the results showed satisfactory performance. This ongoing study has also revealed some areas that still need to be improved upon and is calling for more discussions and sharing of good practices in engineering education matters with special focus on developing thinking skills.

ACKNOWLEDGMENTS

The author thanks Professor Kathleen Nokes from Hunter University in the USA for her valuable contribution and much more needed help in reworking the article in response to the reviewers’ comments.

REFERENCES


