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Problem-Based Learning in Construction Engineering within a South African context

Pauline Machika (Dr)
Vaal University of Technology
South Africa

Chris Abrahams
University of Johannesburg
South Africa

Abstract. The aim of the article is to illustrate how using Problem Based Learning, together with the way in which the content is facilitated, prepares educationally under prepared students in an extended National Diploma over a four year period. A descriptive, exploratory study was undertaken using quantitative data derived from two cohorts of first-year students who enrolled in 2008 for the National Diploma in Construction Engineering and Extended National Diploma in Construction Engineering at a comprehensive university. The results of the extended national diploma shows that with adequate exposure to PBL success can be obtained for students who have not been previously exposed to science and the field of construction engineering. Through this process students are taught to discard old habits and to work accurately. By doing so, they realise the importance of quality work on a construction site. PBL ensures a closer relationship with the lecturer is developed and as a result students in the course feel free to ask questions and clarify understanding in order to make meaning of the problem. This article adds to the existing strategies to support educationally under-prepared students who are enrolled for extended programmes.

Keywords: Problem-based learning; construction; engineering.

Introduction

Students from under-prepared backgrounds often do not see a future for themselves in the fields of science and engineering when they are at high school. This is because the poor standard of mathematics and science teaching at school level produces students with gaps in knowledge and limited science-related experience (Scott et al 2007). Due to their poor schooling these students do not

have the required skills to work in a laboratory or engage effectively with tasks in the fields of mathematics and science. Mathematics and science teachers of schools in disadvantaged communities, as a result of their own level of knowledge and skills (Scott, Yeld & Hendry 2007, p. 42), are often not able to produce learners who perform well in these subjects. Consequently these students either do not meet the minimum standard required for access to selection programmes like engineering, or if they register for such a programme, they struggle to persist and attain an engineering qualification. This has placed the responsibility on higher education institutions to develop a learning environment that will maximise the potential of under-prepared students. Although some students may enter higher education with a history of "low achievement, this is not necessarily related to their capacity to benefit from higher education in the future" (Haggis, 2006, p. 527). Haggis further agrees that the relationship between the lecturer and the student within the learning environment is central to the development of under-prepared students. Recent studies from several different countries have shown that teacher' conceptions of and approaches to teaching correlate strongly with both students' deeper approaches to learning and their learning outcomes (Biggs, 2007; Entwistle & Smith, 2002; Prosser &Trigwell, 2002; Trigwell, Prosser and Waterhouse, 1999 in British Journal of Educational Research 2011). In response to the low graduation rates of students entering university in South Africa (Scott, Yeld& Hendry 2008, p. 9), higher education institutions have introduced new teaching and learning methodologies to foster the relationship between lecturers and students.

Traditional lecturing methods of teaching content and facts no longer support the teaching and learning needs of students. It is argued that problem-based learning can be used to facilitate effective learning for under-prepared students. Extended Curriculum Programmes are first undergraduate degree or diploma programmes that incorporate substantial foundational provision that is additional to the coursework prescribed for the regular programme. The foundational provision that is incorporated must be equivalent to one or two semesters of full time study, it must be designed to articulate effectively with the regular elements of the programme and it must be formally planned, scheduled and integrated as a fundamental part of the programme (Department of Education, 2006:2). It is for this reason that extended curricula are offered over four years instead of three.

Research results show that the understanding of teaching in higher education can be placed into two broad categories (Prosser, Trigwell & Waterhouse 1999 in British Journal of Educational Research 2011). The first category describes faculty who are concerned with teaching as essentially an organisation of the content of the teacher's knowledge for transmission to the students. The second category describes those who regard teaching as facilitating the students' understanding of knowledge and how it can be applied in real-life circumstances. Problem Based Learning provides opportunities to introduce students to new knowledge in the context in which they will encounter it in the world of work. To enable all students with the potential to be able to study engineering, South African universities need to adopt a fresh approach in

understanding which teaching and learning methodology best suits students in order to succeed in maximising their learning potential in the fields of Science and Engineering.

The aim of the article is to illustrate how using Problem Based Learning, together with the way in which the content is facilitated, prepares educationally under-prepared students in an extended National Diploma over a four year period to complete successfully on par with students who were admitted to the National Diploma which is constituted over a three year period in the field of construction engineering.

In the following sections an understanding is developed with regard tounder-prepared students studying construction engineering at a South African university. A discussion follows concerning underlying principles of Problem Based Learning and how problems of under-prepared students could be addressed. The article concludes with a summary of why higher education institutions could use Problem Based Learning in a successful way for students who have been disadvantaged by poor schooling.

Theoretical Framework

With very little exposure to construction work and sites, many under-prepared students have minimal understanding of what construction engineering is about and what it can offer them in terms of career opportunities. Without the correct introduction to the discipline as well as continuous relevant academic support these students may never experience success in higher education. Although the focus has shifted away from the 'deficient student' in higher education institutions (Jacobs & Miller, 2002, p. 85) to how the practices, staff and curriculum of institutions should change in order to meet the distinct needs of non-traditional students, these needs still must be identified. Without full awareness of the problems students experience with regard to the study of construction engineering, a relevant and effective approach to teaching and learning is not possible. The development needs of under-prepared students are multifaceted and complex. They include factors such as difficulty to understand abstract concepts, insufficient academic language proficiency, a lack of effective study and learning approaches together with misconceptions in subject knowledge (Scott, Yeld & Hendry 2007, p. 42). It is necessary to ensure that innovative pedagogical strategies and teaching methodologies that encourage a deep approach to learning (Biggs2007) are employed to develop skills and competencies required for meaningful learning in higher education (HE).

Problem-based learning is a teaching methodology that encourages a deep approach to learning (Yeo 2005). Further Yeo defines Problem Based Learning as a student-centred instructional strategy in which students collaboratively solve problems and reflect on their experiences. The 'Problem Based Learning strategy' encourages students to become active and independent and to take responsibility for their own learning process. Central to the implementation of

problem based learning is the provision of learning opportunities that will address the diverse and individual needs of students while at the same time ensuring the development of lifelong learning skills. Problem based learning is aimed at helping students develop problem-solving, critical thinking, and self-directed learning skills while gaining knowledge in a variety of subject matter areas (Barrows2009). Problem Based Learning is congruent with adult learning theory in that it is based on the use of a real-world problem to facilitate the learning process, encourages students to use their past experiences whenever applicable to solve the problem at hand, requires students to be self-directed learners, and focuses on presenting information in a way that knowledge gained is immediately applicable (Barrows 2009).

Students entering into higher education experience several problems. They might find the Higher Education environment overwhelming and often have a limited understanding of what is required of them in their construction engineering studies. They lack appropriate study and time management skills and many students continue with the rote learning method with which they might have succeeded at school, but which is not sufficient for success in HE. Students enter Higher Education with misconceptions about science concepts (Scott, Yeld & Hendry 2007, p. 42), which hampers their learning in any science-related subject, also in construction engineering. Apart from understanding basic concepts, students also need to learn to 'talk' science, which means that they must learn to "communicate in the language of science and act as a member of the community of people who do so" (Scott, Yeld & Hendry 2007, p. 42). This principle is emphasised by Inglis, Kirkwood, Downs and Parkinson (2007, p. 95) who state that it is important that students learn to "write their way into science" by bridging the gap between the identity they bring from their own backgrounds and experiences and that of the new scientist identity that they need to develop.

A number of studies (Scott, Yeld & Hendry 2007, p. 42; Pretorius2005) have shown that the level of many South African students' basic reading and writing skills and their ability to write in the style of the discipline do not meet the requirements of HE. This contributes to their learning problems, because they are not always able to understand the language and subject-specific language of the learning material, this also applies to understanding construction engineering text books. Students are often second-, third- or fourth-language English speakers. If no support is provided it could be difficult for students to master the contents of these text books.

Krause (2006, p. 8) emphasises meeting students where they are and the need for scaffolding content in order to close the "articulation gap" that students come with from high school when entering higher education. Learning is meaningful only if the integration of previous and new knowledge is part of the learning process(Clayton 2006, p. 197). If students are studying in the construction engineering field implies that they will gain an understanding of construction terminology.

Students experience difficulty in applying the theory that they have learnt in class to real-life and business situations. In a Problem Based Learning setting, the boundaries between the facilitator and the participant are noticeably reduced. This provides opportunities for the participant to feel free to raise pertinent questions to challenge existing issues in relation to a Problem Based Learning problem (Lahteenmaki 2001).The method of teaching used in Problem Based Learning allows hands-on application of theory and exposure to the field.

Applying Problem-Based Learning in Construction Engineering

Central to the field of construction is the ability to measure accurately and to be able to draw building elements as well as to construct three-dimensional models. Without the necessary mathematical ability students will find these kinds of tasks in the construction industry very difficult. At the basis of all skills or competencies that are required is the essential requirement of ensuring that students understand how important it is to produce accurate and quality work. Without this underlying skill construction students will not be able to be effective construction managers. Poor production in the construction field leads to poor productivity within the South African economy.

Problem-based learning is a teaching method where students are constantly challenged to unlearn old learning habits to make way for new ways of learning (Yeo 2005, p. 5).In Problem Based Learning the lecturer provides students with a project in the form of an exercise. The aim of the exercise is to simulate what happens on a construction site by building models. This exercise provides the opportunity for students to learn to be accurate, which is important when ensuring quality on a building site after completion of their studies. Furthermore, it allows a student to develop his or her skills as a team player, which is essential when working as a construction manager. The exercise given to a group of students necessitates the understanding of each group member's role and responsibilities and thus promotes teamwork. It also develops the relationship amongst students as well as between the lecturer and the students. Within a Problem Based Learning setting students are able to ask the lecturer questions directly as they make meaning of construction engineering knowledge. The distance between the lecturer and students is closer as a result of the way teaching is structured within a Problem Based Learning setting (Enger *et al*., 2002). Through the teaching and learning methodology of Problem Based Learning students are given a task that challenges them to brainstorm and generate practical solutions. They are also given the responsibility of taking charge of their own learning, using the chosen 'problem' in the exercise as a guide to decide how to approach the problem in the best possible way (Enger *et al*., 2002).

Example of the procedure for teaching and learning through problem-based learning in construction engineering

As the Problem Based Learning class commences the lecturer will explain to the class in construction engineering an exercise they would have to do as part of

the objectives or learning outcomes in assessing their mastery of the construction engineering theory. Problem-based learning is learning with a particular relevance to prior objectives set – as opposed to conventional spoon-feeding rote learning, evident in trainer-designed didactic settings (Walker, Bridges & Chan, 1996 in Diagnostic Research, 2013) This teaching and learning style will give students an overview of the learning objectives and help them to understand what is expected of them in the teaching and learning process. Once the exercise is explained to students, the lecturer commences to teach as set out in the following steps:

Step 1:

It is essential for construction engineering students to be introduced to construction terminology at the commencement of the course during the first term. In the first term time should be given to helping students understand construction terminology. Apart from understanding basic concepts, students must learn to use the terminology and they must know the rules and values of the discipline so as to act as a member of the discipline's community. If students are poor English-language speakers who have no prior knowledge of construction engineering terminology, they require development that will allow them to engage with the subject field, hence the need to be taught in construction engineering terminology before they are introduced to construction theory.

Step 2:

To facilitate Problem Based Learning the lecturer provides students with the theory of a building site and how the underlying principles must be used to set out different constructions on a real building site. During this time students are afforded the opportunity to ask questions as well as to clarify their understanding of important terminology. Throughout the teaching of construction theory the lecturer is required to support the construction students so as to ensure that they increase their understanding of fundamental principles of the construction field. It is also an opportunity for students to address misconceptions that they might have developed in school or as a result of a lack of understanding. The role of the lecturer within the teaching and learning environment is to create a learning environment that supports the learning activities that are appropriate to achieving the desired learning outcomes (Biggs, 2007).

It is important to introduce theory in small parts since students are still acquiring construction terminology; therefore they might become confused and will not yet be able to use high-order thinking to engage with technical knowledge of the subject field in a complex way. The scaffolding of theory helps students to make meaning of the content provided at each stage. This means that teaching needs to proceed from relatively simple to more complicated competencies. The existing knowledge of the students provides the base platform from which the information is scaffolded in order to provide the support that facilitates understanding (Biggs2007). Keebaugh, Darrow, Tan and

Jamerson (2009, p. 118) report on the effectiveness of Problem Based Learning through sequential and cumulative tasks when students have the necessary support.

Once the theory is taught, the lecturer applies what the students have learnt in theory to practice by developing and building an application model. Lahteenmaki (2001) emphasises that that this process is essential since it provides opportunities for the participant to feel free to raise pertinent questions related to the problem at hand. The lecturer brings all the necessary resources to class and proceeds to build the model. The lecturer uses questioning techniques to clarify understanding, to establish what the students know and to find out whether they are able to build the model on their own. Furthermore, the construction terminology associated with building the model is clarified. In this way the lecturer can ascertain if through their teaching and learning practice, students are able to make meaning of the field of construction. Problem Based Learning is a form of group mentoring and is defined by Barkham (2005) as a process through which a career may be guided, beginning with induction into a profession or institution through to progress and promotion with positive outcomes not only for individuals involved, but also for their universities or organisations. Through Problem Based Learning, lecturers are the most important change agents in their own setting and it is vital that they should feel that they have control over their situation (Knight & Trowler, 2009).

Step 3:

After the teaching of construction theory, the lecturer must identify the students' learning outcomes by assessing how they have applied and adapted the course content to reach a viable solution to the problem in the exercise given. An example of an exercise given to construction engineering students is seen in Exhibit 1.

Exhibit1**:** The instructions to students are in the text box below:

In the sketch provided to you as a group, the building lines of a gazebo are shown which has three walls. The one-brick wall is built on a 680 wide strip foundation. Draw the given top view of the building lines to a scale 1: 20, as well as the profile boards in position to mark off only the walls marked 'A' and 'B'. Indicate the trench markings for the foundation trenches as dashed lines.

In the example in Exhibit1, the students must accurately draw everything on scale 20 times smaller than reality. The problem, albeit a simple structure having only three walls, is designed to test if students are able to perform the essential steps in setting out a building on site. By the time the students do this exercise they will have learnt how to calculate the width of a trench when given only the wall thickness (220mm) as well as the strip foundation thickness (230mm). They will also have drawn to scale the profile boards which are used to mark off the excavation trenches and also to guide the bricklayer when he builds the first

course of the foundation wall. The use of a practical problem through Problem Based Learning develops learning from a concrete experience where students are able to reflect on existing facts to discover the different areas of the practical problem (Yeo 2005).

Students are allowed to choose members of the class they wish to work with in a group. The lecturer then provides them with the learning outcomes for the exercise which the students are required to build while applying theory. Enger *et al*.(2002) state as an example that students are given a task through Problem Based Learning which challenges them to brainstorm and generate practical solutions. They are also given the responsibility of taking charge of their own learning, using the chosen 'problem' in the exercise as a guide to decide, based on the scope, how to approach the problem in the best possible way.

Step 4:

Students need to realise that they are required to be innovative and creative when constructing assignments within the group they have chosen. This prepares them for teamwork in the construction industry. Problem Based Learning is prominent in human resource development, particularly in leadership training, with curricula directed at independent and team learning (Bridges and Hallinger, 2007). Since students are trained to be construction managers, Problem Based Learning is a relevant method in construction engineering. Rather than receiving a body of factual knowledge about the world, students are understood as agents, actively negotiating their way in the world (Yeo 2005).

According to Kirkwood, Downs and Parkinson (2007, p. 83) group presentations at the end of the semester provide students with an opportunity to personalise their knowledge acquired during the course. These authors further state (2007, p. 89) that it is important to assess the students' ability to perform an authentic task. The exercise in Exhibit 1is given to construction students working in a group rather than assessing discrete skills in separate tasks. Knight and Trowler (2009) maintain that it is important for skills and academic components of each part of the course to be carefully integrated into practical simulations to ensure that students have the necessary academic knowledge and problem-solving skills to adequately address the particular exercise in construction engineering.

Step 5:

Problem-based learning after grading focuses on giving students feedback to improve their learning (Biggs 2002). Feedback is an indispensable element of all assessment opportunities and the monitoring of students enables staff to implement timely support interventions. After the Problem Based Learning construction exercise is assessed it is important to provide feedback to each of the groups timeously. The feedback given provides students with an

opportunity to critically assess what they as students know and the manner in which they have translated theory into practice. Feedback from the lecturer is critical for the students and helps them to understand the construction context and what is expected of them within the field of construction engineering.

Biggs (2007) states that students should be encouraged to develop increasingly difficult critical analytical abilities as they progress. However, under-prepared students must first master the basic learning objectives, namely knowledge, comprehension and application of the learning matter before higher-order thinking skills can be developed. By using Problem Based Learning and prompt feedback on students' performance, lecturers can help these students to achieve academic success (Yeo 2006).

Methodology

This descriptive study used quantitative data derived from two cohorts of first-year students enrolled for the National Diploma in Construction Engineering and Extended National Diploma in Construction Engineering at a comprehensive university. The data was extracted from the University's Management Information System and student record systems. The groups were the 2008 cohort of students who were admitted to the extended National Diploma in Construction Engineering and the 2008 cohort of students who were admitted to the extended National Diploma in Construction Engineering. Each student's record was analysed individually to see if they had already graduated within the minimum required time or had lengthened their period of study beyond the minimum duration of the programmes respectively or whether they were still in the process of completing.

Results and Discussion

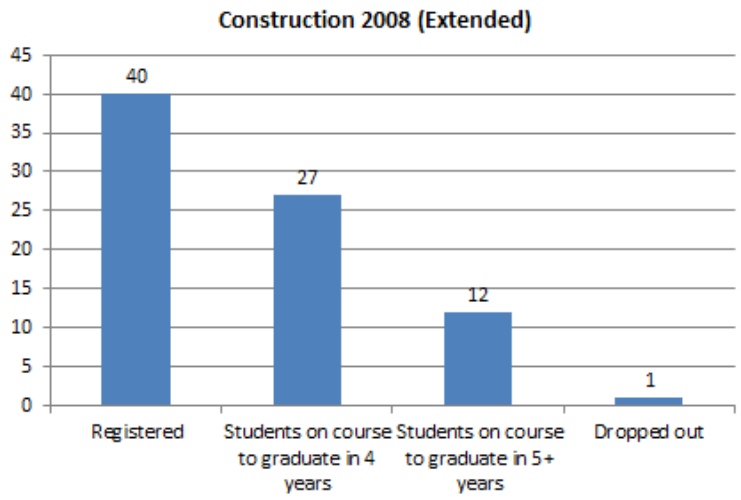

Figure 1: Construction 2008 (Extended)

In 2008, 40 students were registered for the extended National Diploma in Construction Engineering (see Figure 1). Only 1(2,5%) of these students dropped out and 27(67,5%) were able to complete the National Diploma in a four period. The normal completion period for the Extended National Diploma is four years and includes foundational provisioning in the first year, followed by two years of theory and one year of work integrated learning. A further 12 (30%) students were able to complete the national diploma in construction engineering in five years rather than the required four years.

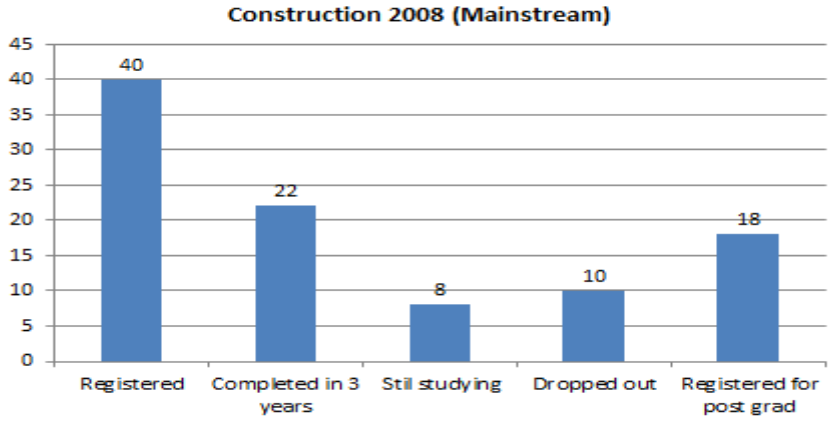

Figure 2: Construction 2008 (Mainstream)

In 2008, 40 students were admitted to the National Diploma in Construction Engineering. The normal completion period for the National Diploma is three years and includes by two years of theory and one year of work integrated learning (see Figure 2). Of the 40 students who were registered for the programme only 22(55%) were able to complete the National Diploma in a three period. While a further 8(20%) were able complete the national diploma in construction engineering with an additional year. It was interesting to note that only 10 (25%) were not successful and were unable to complete their studies.

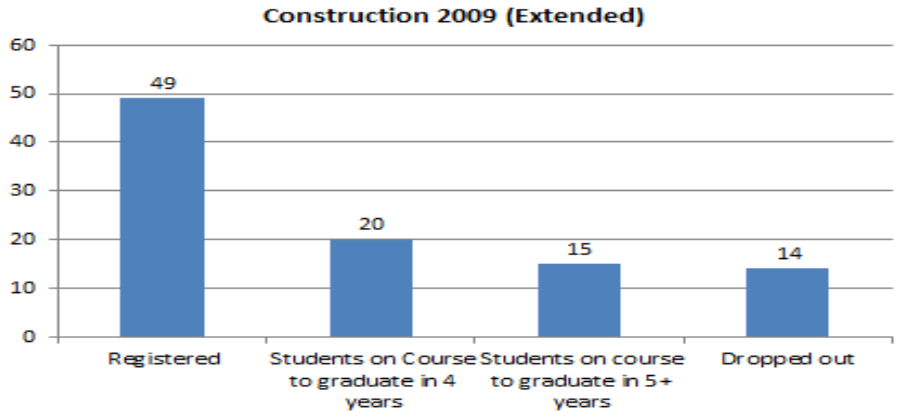

Figure 3: Construction 2009 (Extended)

In 2009, 49 students were admitted to the Extended National Diploma in Construction Engineering The normal completion period for the Extended National Diploma is four years and includes by three years of theory and one year of work integrated learning. (see Figure 3).

It was of interest to see that only 20(41%) students were able to complete the extended national diploma in the allotted time. While a further 15(30%) added an extra year onto the allotted time provided for the qualification. From the total number of 49 students registered 15(30%) were unsuccessful and did not complete their studies.

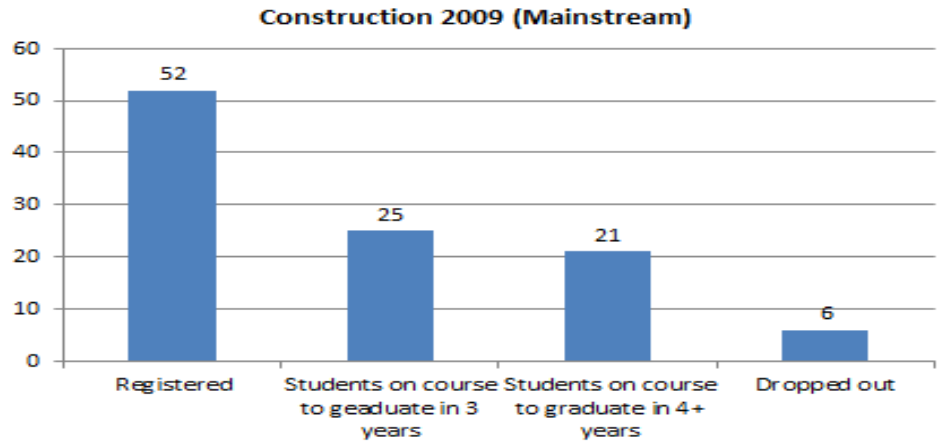

Figure 4: Construction 2009 (Mainstream)

In 2009, a total number of 52 students were successfully admitted to the National Diploma in Construction Engineering. The normal completion period for the National Diploma is three years and includes two years of theory and one year of work integrated learning (see Figure 4). Of the registered number of students only 25(48%) were able to successfully complete in the stipulated time of the qualification. A further number of 21(40%) students completed with an additional year. While a number of 6(12%) students were unable to complete the qualification successfully.

Discussion of Results

A comparison of Figures 1 and 2, as well as Figures 3and 4 shows that students completed the extended diploma in Construction Engineering with the PBL methodology on par with the mainstream students. With very little exposure to construction work and sites, many disadvantaged students possess minimal understanding of construction engineering. As a result of this, students may not experience academic success.

There are several benefits in applying Problem Based Learning in construction engineering with students who have been under-prepared due to inadequate or

poor schooling. Students develop an understanding of what is expected of them in the course they are studying through PBL, and are engaged in the learning process as team members. Through this process students are taught to discard old habits and to work accurately. By doing so, they realise the importance of quality work on a construction site. This is supported by Biggs (2005) who explains that innovative pedagogical strategies and teaching methodologies encourage a deep approach to learning and are employed to develop skills and competencies required for meaningful learning in higher education. Barrows (2009) states that PBL is based on a real-world problem presented in class to ensure the facilitation of the learning process. Construction engineering students are taught terminology and how to apply it in the field. PBL ensures that a closer relationship with the lecturer is developed and as a result students in the course feel free to ask questions and clarify understanding in order to make meaning of the problem.

Enger et al. (2002) supports the closer relationship between the lecturer and student as PBL provides opportunities for the participant to feel free to raise pertinent questions to challenge existing issues. Enger et al. further mentions that PBL gives students agency because they have the responsibility to take charge of their own learning by deciding how to approach the chosen "problem" in the exercise. By scaffolding theory through PBL, lecturers are able to assess students' gradual mastery of construction theory. Through working as a group while solving the problem in the exercise, students consider various options and understand how best to address the problem and find a solution to it. The PBL methodology furthermore ensures that, students are given feedback which helps them understand where they went wrong, how they can improve their performance and how to master the problems in construction engineering. Through the Problem Based Learning teaching methodology approach, students are able to be reflective of their own practice and are taught to work accurately, which is essential when working in a construction field.

Conclusion

The focus of this article is to show how innovative strategies can provide under-prepared students with the required knowledge and skills to be as successfully as mainstream students. To achieve this problem based learning was used in the extended national diploma in construction engineering. The study shows several benefits when applying Problem Based Learning in a construction engineering programme. Further research should be conducted concerning the impact PBL can have on the academic success of students who have registered in the mainstream. Consideration could be given to gathering data from both extended and mainstream student groups who had experienced PBL and compare the benefits of this method in different contexts. To ensure academic success for students from under-prepared backgrounds, teaching and learning should not focus on the organisation of the content of the teacher's knowledge for transmission but rather on innovative teaching methodologies like Problem Based Learning which can enable students to be successful in fields like construction engineering.

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In memory of Mr Chris Abrahams who passed away tragically in 2013. Gone but not forgotten.

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