Art. # 457, 16 pages, http://www.sajournalofeducation.co.za

# Introducing problem-based learning (PBL) into a foundation programme to develop self-directed learning skills

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*This article reports on the qualitative aspects of a study that examined whether introducing a* Problem-based Learning (PBL) *approach in a one-year foundation programme can create conditions for learners to develop and sustain self-directed learning skills. This interpretive-constructivist case study was located in evaluation research. Data were collected by means of classroom observations and interviews with 35 students and 14 former students. Findings indicated that introducing students to a PBL approach did promote more meaningful learning patterns, typified by processing the subject matter critically and self-regulating learning processes. The sustainability of the meaning-directed learning skills was questionable if student beliefs in the approach did not support the activities employed. Introducing PBL into a foundation programme can develop self-directed learning skills in students and set in motion a process of growth towards lifelong learning.*

**Keywords:** disadvantaged learners; evaluation research; foundation programmes; lifelong learning; Mathematics and Physical Science education; Problem-based Learning; self-directed learning; self-regulated learning

## Introduction

The diverse student intake into higher education in South Africa has changed not only in terms of numbers, but also in terms of preparedness (Quinn, 2003). The traditional way of teaching encourages learner dependency and superficial understanding, and fails to encourage reflection and self-direction (Engelbrecht, 2001). The more diverse student population has heightened the need for a broader range of teaching and learning approaches at tertiary level. Many higher education institutions are expanding their foundation programmes in order to provide learning opportunities that support students as self-directed, independent learners (Adendorff, 2006; Kgaphola, 1999).

Science and Mathematics at Stellenbosch University (SciMathUS) is an intensive, year-long foundation programme that recruits and gives socio-economically disadvantaged students a second chance for access to university mainly in the Natural, Health, or Economic and Management Sciences. Recognising that social, economic and educational disadvantages contribute to students' poor performances in Grade 12 (Department of Basic Education, 2010), the programme allows students to rewrite the Senior Certificate examinations in Mathematics and Physical Sciences. The aim is that, once students have completed the SciMathUS year, they qualify for tertiary programmes in selected courses and are adequately equipped to succeed at their future tertiary studies (Michaels, 2005).

Before 2005, teaching at SciMathUS mainly focused on the content of the Grade 12 curriculum and the quality of the knowledge the educator controls. One likely consequence of this teacher-centred approach is the development of a closed conception of teaching and a reproductive, superficial conception of learning which strengthens learner dependency (Engelbrecht, 2001). A PBL approach was introduced into the programme in 2005 to enhance the students' chances of success in higher education. Several studies reveal that PBL supports students as self-directed learners and provides them with a more realistic picture of the academic challenges that they have to face in higher education (Dunlap, 1997; Johnston & Tinning, 2001; Mierson, 1998). This article presents the learning experiences of 35 former SciMathUS students to indicate ways in which self-directed learning patterns werepromoted.

## The PBL philosophy of the programme

The PBL philosophy adopted by SciMathUS strives to equip students with the underlying skills and attitudes needed for lifelong learning (Johnston & Tinning, 2001). As second chance learners they cannot be taught by the same traditional methods that previously failed them. PBL prescribes a student-centred learning environment in which students are not viewed as empty vessels (Freire, 1985; Mierson, 1998), but as bringing their own perceptual frameworks and different learning styles, to an active, dynamic learning process (Adendorff, 2006). In PBL the starting point for learning is a real-world or ill-structured problem, the resolution of which requires students to work cooperatively in small groups (Dunlap, 1997; Limerick & Clarke, 1997). PBL provides students with a learning environment where they are stimulated to become more involved and take on more responsibility for the learning process. PBL involves a shift from content coverage to problem engagement; from lecturing to coaching; and from students as passive learners to that of active problem-solvers (Finucane, Johnson & Prideaux, 1998). This is quite different from most university teaching approaches which concentrate on the transmission of factual knowledge (Yeung, Au-Yeung, Chiu, Mok & Lai, 2003).

PBL can be considered to be constructivist in nature (Tynjälä in Newman, 2004). Constructivism is based on a view that 'knowledge' is not absolute, but is actively constructed by the student based on previous knowledge and overall views of the world (Baker, 2000; Oxford, 1997). It therefore represents a significant break with traditional approaches. In the SciMathUS context, PBL is viewed as a combination of cognitive 'scientific' and social constructivist theories (as developed by Piaget and Vygotsky) in which learning is viewed as an activity that not only takes place within individuals, but also occurs when they are engaged in social activities (Kim, 2001; Von Glasersfeld, 1995). The focus shifts from restricted content to the development of conceptual understanding that fosters deep rather than surface learning. Content remains important, but there is more emphasis on the process of learning (Williams, 2001).

### Nature of instructional practices

SciMathUS needed a Hybrid PBL approach (an adapted version of PBL) that suited our programme needs most, since it allowed us to implement PBL in shorter cycles and integrate only the main subjects (Newman, 2004). Integrated teaching sessions, where lecturers in Mathematics and Physical Science taught together in one classroom, were introduced in addition to subject-based teaching, where lecturers taught their subjects separately. Three large-scale PBL problems were designed for each term and the sessions brought together areas of interest common to each of the two main subjects.

We combined the seven-jump approach of the University of Maastricht (Schmidt, 1993) and the Howard Barrows PBL model (Barrows, 1996), since these models provide a more structured way of approaching problems and of developing self-directed learning skills. Figure 1 illustrates the basic steps of the PBL process employed at SciMathUS.

The steps involve students encountering a problem, clarifying working definitions of unclear terms or concepts, producing an exact definition of the problem, analysing the problem components, clustering ideas, identifying learning issues in an interactive process, researching the learning issues through self-study, applying newly gained knowledge to the problem, and summarizing what has been learned. The process concludes with students evaluating the experience. The students' self-directed learning time is the period between the problem presentation and problem discussion meetings.

### The links between PBL and self-directed learning

Various principles govern the design of PBL based on self-directed and self-regulated learning theory. Newman (2004) emphasizes that successful learning requires the adoption of particular attitudes (or beliefs) and strategies (or activities). Self-directed learning (SDL) refers to the goal-dimension towards lifelong learning, i.e. an internal change in consciousness or beliefs whereas self-regulation (SRL) refers to the actual activities or strategies necessary to move towards the goal of SDL (Rodríguez & Cano, 2006). When the external technical dimension (SRL) is fused with the internal, reflective dimension (SDL), the most complete form of self-directed learning occurs (Brookfield, 1985).

Most students are not homogeneous in their background, knowledge, experience, learning abilities or learning styles. The self-directed activities which are embedded in every PBL phase suit students' diverse learning needs well (Siaw, 2000).The development of meta-cognition is also an important part of developing the skills associated with self-monitoring which contribute to the students' ability to become lifelong learners (Williams, 2001; Van Loggerenberg-Hattingh, 2003). PBL develops these skills when students establish educational goals and create action plans to meet those

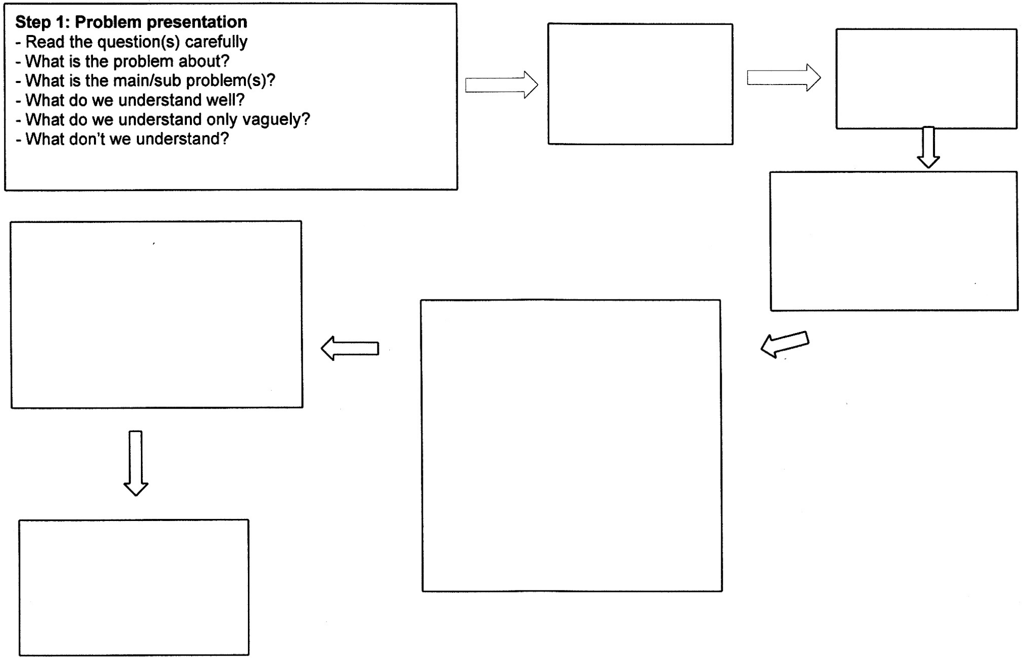


Figure 1 PBL process at SciMathUS

goals, reason aloud through discussion, reflect on their knowledge base, formulate and test hypotheses, clarify understanding through negotiation of meaning and critique and defend each other's points of view. These activities, when facilitated effectively, assist the students to develop self-monitoring skills necessary to identify learning progress and reveal their internal thinking processes. In this way students develop the independence and motivation to pursue the necessary self-directed and self-regulated learning via the best resources (Miflin, 2004; Williams, 2001) for lifelong learning (Johnston & Tinning, 2001). This logically leads to the necessity to examine learning styles that typify self-directed and self-regulated learning.

### Vermunt's Inventory of Learning Styles

Based on constructivist views of learning, Vermunt (1994; 1998; 2004) proposed an Inventory of Learning Styles (ILS) which integrates four components of learning: cognitive processing strategies, meta-cognitive regulation strategies, students' mental models (conceptions) of learning, and their learning orientations (motives). The first two of these are the self-regulative components (Linares, 1999) whereas the last two are the self-directive components (Vermunt & Vermetten, 2004). Using explanatory factor analysis, Vermunt identified four different learning patterns or styles: a meaning-directed style, a reproduction-directed style, an application-directed style and an undirected style (Boyle, Duffy & Dunleavy, 2003). A meaning-directed style is typified by relating, structuring, and processing the subject matter critically, self-regulating learning processes and contents, constructing knowledge as learning conception, and personal interest as learning orientation. A reproduction-directed style favours memorising and rehearsing, analysing, external regulation of learning, certificate and self-test directed-learning orientations, and a learning conception in which learning is viewed as the intake of existing knowledge. An application-directed learning pattern is typified by concrete processing, a vocational learning orientation and a learning conception stressing the use of knowledge. Finally, an undirected learning style favours a lack of regulation, an ambivalent learning orientation, and a learning conception in which great value is attached to cooperation with fellow students and to lecturer stimulation. From the viewpoint of high-quality learning, the meaning- and application-directed learning patterns are more desirable and may improve academic achievement (Bothma & Monteith, 2004; Rodríguez & Cano, 2006).

The sustainability of meaning-directed learning activities is hindered if student beliefs in the approaches (SDL) do not support the activities (SRL) they employ. According to Brookfield (1985) and Rodríguez and Cano (2006), the most complete form of self-directed learning thus occurs when the external technical dimension (the SRL activities) is fused with the internal, reflective dimension (the SDL beliefs). This leads us to the research question of this study.

### Research question

Does introducing a PBL approach within a one-year foundation programme create conditions for learners to develop self-directed and self-regulated learning skills?

## Empirical study

### Research design

This article reports on the qualitative findings of a PhD study conducted from 2005 to 2007. This single-case foundation programme (SciMathUS) study was located in evaluation research (Rossi, Lipsey & Freeman, 2004). The interpretive-constructivist paradigm with a pragmatic focus was adopted, typified by an emphasis on the insiders' perspective, location of the research in the natural setting of social actors, seeing the researcher as the 'main instrument' in the research process and the product of the inquiry as richly descriptive (Morgan, 2007).

### Ethical considerations

Approval to proceed with this study was granted by the university ethics committee. The first author obtained written consent from the programme manager, lecturers and students who were to be involved in the study. The participants' anonymity and confidentiality were maintained through the use of pseudonyms (e.g. Student response 1).

### Samples

In this single case-study the researcher used purposive sampling. During 2007, 35 adult male and female SciMathUS students from socio-economically disadvantaged families (aged between 17 and 22) and three educators (two Mathematics lecturers and one Physical Science lecturer) were interviewed and observed prior to and after a six-month period of PBL exposure. Qualitative data by means of open-ended structured questionnaires were also obtained from 14 randomly selected 2006 first-year students, eight months after they had been introduced to the PBL approach at SciMathUS. The data were used to determine the sustaining effects of the PBL approach used in the programme and the participants' general experiences in higher education.

### Data collection procedures

Qualitative data were generated from the 35 students as well as the three lecturers through semi-structured focus group interviews and classroom observations. Three focus group interviews (with six to eight students per group) were conducted at the research site directly after students completed three PBL problems during each term. The interviews, based on a review of the literature, aimed to explore students' learning patterns after exposure to PBL problems to ascertain any changes in self-regulated skill levels, values and beliefs as well as their experiences of the whole PBL process. Empirical classroom observations included what participants were saying and doing in relation to working on actual PBL tasks and the skills and attitudes they displayed.

The researcher further wrote down how the class atmosphere was experienced, how the problems were approached and completed and described the interactions between the learners and learners and tutors. The interviews with the three lecturers were conducted separately at the research site immediately after the student interviews focusing on the quality of the problems, the quality of student-tutor interaction and their experiences of the PBL process.

An open-ended questionnaire which consisted of 7 questions targeted the 2006 students eight months after they had been introduced to the Hybrid PBL approach, to demonstrate whether learners could apply what had been learned in the programme within the university environment and the participants' general experiences in higher education.

### PBL Context Problems dealt with

#### *Problem1: The Global Warming and Power Plant Problem*

Students were given a global warming problem to investigate the causes of global warming, its socio-economic implications and the precautions required when constructing a Power Plant, or possible solutions to be considered to mitigate the effects of global warming. The students were divided into groups; some focusing on the scientific aspects of the problem while others focused on the economic implications. They were to prepare and present a poster showing their group's findings.

#### *Problem 2: The Amazing Race Problem*

Given a map and clues, students were to find specific destinations and be able to work together as a group, interpret the clues and follow instructions, read the map accurately and follow the routes. They were instructed to record the time taken to find each destination and use the scale of the map to calculate the distances covered and ultimately calculate the average speed for each route taken. They were to write a letter to their lecturers describing how they experienced the race.

#### *Problem 3: The Two Oceans Marathon Problem*

The students were to analyse the data for the women athletes (Veteran Category) who participated in the 2007 Two Oceans Marathon and make recommendations to the Organising Committee of the 2008 edition of the Marathon about how the speed of each athlete over each stage can be determined or to carry out the calculations. In 2007 only data about time taken by each athlete had been collected as each athlete covered the various stages of the race (28km and 42.2km at 5km, 24km, 35km, 42km) until they reached the finishing line of the 56km race. The analyses and recommendations were to be presented in the form of a well-explained, well-illustrated five page group report.

### Data analysis procedures

We used the four components and patterns of student learning identified in the ILS questionnaire as well as those obtained from our literature review for the classification of *qualitative* interview responses. We developed themes and counted the number of times they were indicated by students and groups in the text data. The categories on the ILS questionnaire provided a useful tool in both the insights being sought and in managing and organizing the extent of data being gathered from interviews and observations (Ely, 1991). The components on the ILS questionnaire guided both data construction and analysis, and provided an explanatory framework for the interpretation of findings (Babbie & Mouton, 2001).The results and discussion of results now follow in greater detail.

## Results

The statements given in the following section are from spontaneous comments made by students and lecturers in interviews.

### Evidence of meaning-directed learning patterns

Prior to PBL exposure, qualitative results indicated a lack of deep processing strategies with all of the 35 students indicating a survival mentality to do things the easy way on entering the programme. This was reflected in the roles the students assumed as learners and the expectations they held about their lecturers.

> "*The task of the lecturer is thorough preparation before class, presenting work the easiest way possible, checking progress regularly and thinking about ways to improve it*" (Student response 1 prior to PBL exposure).

The participants in the study expected to be mostly taught by their lecturers and to be directed in their studies both of which would leave them as dependent and passive learners:

> "*They* (the lecturers) *must present the work correctly and simply, they must be able to answer all my questions and provide me with a bit of inspiration*" (Student response 2 prior to PBL exposure).

After exposure to PBL, qualitative data indicated an increase in students who were employing meta-cognitive strategies of self-regulation of learning processes and outcomes in their individual studies by being active and taking on more responsibility for their learning.

> "*My methods of studying is different, I'm more active now*" (Student response 3, after PBL exposure).
>
> "*I take my work in my own hands now and don't wait for others to spoon feed me*" (Student response 4 after PBL exposure).

After the PBL exposure, qualitative results also indicated improvement in the employment of deep processing strategies (relating and structuring) by students. They recognised, for instance, that knowledge transcends artificial disciplinary boundaries.

> "*PBL shows you how your subjects are related which improve understanding*" (Student response5 after PBL exposure).
>
> "*We enjoy the problems, it gives us insight*" (Student response 6 after problem 1).

"*The lecturers wanted us to see that real-life problems have a strong correlation with the math and science we do here in SciMathUS*" (Student response 7 after PBL exposure).

"*PBL changed the way we think. We understand math, the calculus part and also physics; the relationship between gradient and velocity, etc.*" (Student response 8 after PBL exposure).

The lecturers further confirmed that the groups realized the importance of reasoning logically: "*They now realise how important it is to reason logically*" (Lecturer 1 after PBL exposure).

The students also showed some deep processing strategies of critical and reflective processing:

"*Through constructive criticism and by evaluating whether or not we have answered the questions we determined whether we have grasped the problem*" (Student response 9 after PBL exposure).

"*I question things more and don't just accept things*" (Student response 10 after PBL exposure).

Although the activities employed by students after PBL exposure indicated use of deep- processing learning strategies, some students still experienced conflicting beliefs regarding self-regulated learning and specifically their responsibility for constructing knowledge in the learning process.

"*They* (the lecturers) *must tell me where I've made mistakes so that I can try again. They must encourage me sometimes when I get discouraged and negative. They must make sure that the work that I'm doing is correct*" (Student response 11 after PBL exposure).

"*The lecturer must support, provide necessary information and motivate*" (Student response 12 after PBL exposure).

The few qualitative changes noted towards the application of more meaning-directed learning activities employed by learners included the following remarks:

"*I learn differently than in the past. I plan now what I need to do*" (Student response 13 after PBL exposure).

"*There is a change. I realized not everything can be taken for granted like we did at school but that I have to work very hard and think well*" (Student response 14 after PBL exposure).

### Evidence of application-directed learning patterns

The qualitative results revealed changes in the students' application-directed learning patterns. Their cognitive processing became more concrete and realistically oriented and the students reported greater motivation to learn as the following responses indicate:

"*We loved it. It took us beyond the text book and we find it prepares us for the outside world*" (Student response 15 after PBL problem 1).

"*I have experienced that my studies are real. It helps us to grasp the relevance of* *math and how science occurs in our daily lives*" (Student response 16 after Problem 3).

"*We enjoyed the part where we had to apply calculus to help us find the instantaneous velocity*" (Student response 17 after PBL problem 3).

After exposure to PBL, students shifted their learning conceptions from mere textbook learning to applying learnt knowledge as the following responses suggest:

"*PBL encouraged us to apply our knowledge instead of working out of a textbook. It creates a clear picture about textbook theory and real life problems. Math and science happens in everyday life*" (Student response 18 after problem 2).

"*PBL helps me to use the mathematics concepts in solving real world problems*" (Student response 19 after problem 2).

"*It familiarized us with problems that we actually do face and makes us apply our knowledge in everyday life*" (Student response 20 after PBL problem 2).

"*We have acquired information with the purpose of using it in our future and to implement it in practical situations*" (Student response 21 after PBL problem 3).

The students also showed some shift in their learning orientations about vocation-directedness as the following responses suggest:

"*PBL helps me feel like a professional*" (Student response 22 after PBL problem 3).

"*The kind of questions you get at varsity gives you an understanding of what is expected in your future career*"(Student response 23 after PBL problem 3).

### Reduced incidence of reproduction-directed learning patterns

The qualitative data pointed to some significant changes in the students' reproduction-directed learning patterns. After exposure to PBL, their cognitive processing activities indicated a significant decline in the use of the stepwise learning strategy of rote memorisation. Prior to PBL exposure, 20 students assumed that learning comprises rote memorisation of facts:

"*I call my way of studying parroting 'papegaai leer'. I memorise everything precisely like it appears in the textbook and write it down so that I can remember it*" (Student response 24 prior to PBL exposure).

After exposure to PBL, qualitative results indicated that only five out of the 35 students still focused on memorising. This was especially noted by the lecturers.

"*I believe in PBL. I notice that the students think rather than memorise. Students are thinking critically about the questions and their answers are not just parroting. This has really made our students think*" (Lecturer 3's comments after PBL exposure).

There were however some students, albeit fewer, who did not seem to change as the following cognitive processing responses of rehearsal and meta-cognitive self-regulation responses of external control showed.

"*Most of the time I cram my work on the last minute, thinking I won't forget it but at the end of the day I normally forget everything I've studied*" (Student response

25 after problem 3).

"*When it's theory I read aloud and rehearse so that I can store the information in long term memory*" (Student response 26 after problem 3).

"*We didn't like it that there wasn't a direct way to get to the right answer. We disliked not knowing better how to go about getting answers so we asked help from the tutors*" (Student response 27 after problem 3).

The qualitative data after exposure to PBL revealed that fewer students (from 20 to only 11 students) were still applying the stepwise processing strategy of analysing and still believed in learning as mere absorption of knowledge. According to the lecturers the few students who viewed learning as the intake of knowledge by reproducing facts tended to experience PBL negatively since they felt insecure with the process:

"*We did much smaller PBL problems in the class. Some of the students however did not experience this positively. They feel insecure with the PBL process. They like lectures and facts*" (Lecturer 2 after PBL exposure).

The significant decline in the use of the stepwise learning strategy of rote memorisation and the fact that fewer students still believed in learning as mere absorption of knowledge was conducive to the development of meaning and application-directed learning patterns.

### Reduced incidence of undirected learning patterns

Although many students had significantly shifted towards meaning-directed and application-directed learning patterns as reported above there was still occasional resort to undirected learning patterns. For example, some groups showed lack of effective metacognitive self-regulation as they underestimated the problem statement, showed a lack of collaboration, poor time management and struggled to process large amounts of information:

"*We need to structure our working in our group better.*" "*We did not use our time effectively.*" "*We finished too early.*" "*It is tough to prioritize all the information.*" "*We underestimated problem 2.*" (Group reports after PBL exposure)

"*The past problems were fun and I learnt from them but this one left me with a lot of unanswered questions. For example what was the point of it all? I'm not sure what we were supposed to learn from it*" (Student response 28 after problem 3).

Lecturers confirmed the persistence of some of these patterns and it was clear that more guidance during the facilitation process was needed.

"*It was clear that the students were not aware of the credibility of the different types of resources.*" "*I noticed groups going off on tangents, not focusing on what the crux of the matter was – what was actually being asked and how can this question be answered and the answers justified.*" (Lecturers 1 and 3 after PBL exposure)

### The sustainability of the meaning-directed learning skills

We explored the sustainability of the meaning-directed learning skills next. Eleven of the 14 randomly selected 2006 students indicated that they were able to use some of the skills they had learnt eight months after being exposed to PBL in their tertiary studies when completing projects, assignments and practical work where research is required, whilst three did not acknowledge using specific PBL skills.

> "*I benefit from a few things that we did in PBL like assignments and writing essays but most of my courses are not like we get many things that we have to think out of the box or use our thinking*" (Student response 29 eight months after PBL exposure).
>
> "*My classes are still very much like school where the teacher stands in front and talks and we do the listening*" (Student response 30 eight months after PBL exposure).

**Discussion**

The findings indicated that it is possible for the PBL approach adopted at SciMathUS to influence student learning patterns in a favourable direction. In particular the results show some shifts towards meaning-directed and application-directed learning patterns. For example, on the self-regulated learning (SRL) cognitive processing activities, the results show that exposure to the PBL approach did promote the use of deep-processing learning strategies, typified by processing the subject matter critically whilst making less use of surface approaches to learning such as memorising and rehearsing. Working in groups did allow for critical reflection and consensus building based on justification before findings could be taken-to-be shared (e.g. Student responses 9 and 10). In addition, the students appeared to make more use of meta-cognitive self-regulating activities such as planning, diagnosing the problem, testing their outcomes, and adjusting and reflecting on their solutions (e.g. Student responses 13 and 14 and Group reports). Student responses also showed that they were less dependent on lecturer stimulation (e.g. Student response 4).

However, not all students shifted in their cognitive processing strategies as expected (e.g. Student responses 11 and 12). There was evidence of tensions between previous experience of traditional learning and the PBL approach. For example some students demanded to know the correct answers from the lecturers (e.g. Student response 27, Lecturers 2 and 1 and 3) signifying inability to consistently take responsibility for justifying the accuracy of knowledge construction processes (unstable meta-cognitive self-regulation).

The sustainability of the meaning-directed learning activities employed by students was also questionable. Student beliefs (SDL) regarding their responsibility for constructing knowledge and their responsibility in the learning process did not always support the activities (SRL) they employed as shown by the occasional resort to reproduction-directed and undirected learning patterns (e.g. Student responses 25, 26, 27, and 28 as well as lecturers 1 and 3's comments). The fact that students are exposed to conventional approaches in higher education, often characterised by an absence of follow-up strategies to apply what has been learned, may further impede sustainability (e.g. Student response 30 eight months after PBL exposure). Peter Bouhuijs (pers. comm.), for instance, stated that the challenge to sustainability is that there is no methodology for PBL if it is only introduced in the foundation year, especially if higher education institutions use conventional approaches in their degree programmes. Bouhuijs stressed the importance of the PBL initiative being successful and being relevant when it is not just about the students surviving the foundation year, but about their succeeding in their tertiary studies.

## Conclusion

The purpose of this study was to determine whether introducing a PBL approach within a one-year foundation programme created conditions for learners to develop self-directed and self-regulated learning skills.The findings indicated that it is possible to influence student-learning patterns in a favourable direction, if appropriate PBL context problems of interest to the learners are selected and integrated into the curriculum; if learner roles and responsibilities in the collaborative groups are clearly defined and emphasised, and if lecturers de-role from knowledge dispensers to facilitators of knowledge construction and transformation. In this regard we take note that in an educational setting Tan (2004) also found that whilst PBL was a promising approach to educational innovation, implementation deficiencies can occur resulting in a lack of direction for both students and staff. The sustainability of the meaning-directed learning activities employed by students can be hindered if there is a disjuncture between students' beliefs regarding their conceptions of learning and the cognitive processing and self-regulation activities they apply. Exposure to conventional approaches in higher education can further impede sustainability if follow-up strategies do not encourage application of learnt skills. Nonetheless, when considering the shift towards more meaningful and application-directed learning patterns, and the reduced incidence of reproductive and undirected-learning patterns, we believe that introducing students to PBL did create conditions for learners to develop self-directed and self-regulated learning skillsand set in motion a process of growth towards lifelong learning.

### Limitations of the study

The results of the study reported here are limited to the qualitative feedback. To determine the singular impact of the programme on overall academic performance of the learners, it would require a classical experimental design that would control for other factors such as the new tertiary environment that the learners are exposed to and the very fact that these learners would be repeating. Further research is required therefore to determine the throughput rate of the learners once admitted into their future studies to ascertain whether indeed the SciMathUS students are better prepared for lifelong learning than comparable students.

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