

>> A PILOT STUDY IN AN UNDERGRADUATE PHYSICAL SCIENCES TEACHER EDUCATION PROGRAMME

Learning How to Use the Laboratory through Problem-Based Learning

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Introduction

There is some evidence that teachers tend to teach the way they were taught (Murray-Harvey and Slee 2000). Therefore, innovative science teacher education is a necessary requirement for changing science teaching in schools. Despite the fact that the Portuguese curriculum for compulsory education places the learner at the centre of the teaching process and acknowledges modern teaching methodologies (DEB 2001), teachers often ignore the curriculum proposals and keep their traditional ways of teaching. Problem-Based Learning (PBL) is an active learning methodology that leads students to acquire new conceptual knowledge and to develop problem-solving competencies by solving problems (Boud and Feletti 1997, Lambros 2002). Despite the great educational potential of PBL, this methodology has not yet engaged enough Portuguese teacher educators' attention. Besides, using this methodology would be a challenge for teachers (Lambros 2002, Lambros 2004), as it requires them to play a quite different role – instead of knowledge deliverers they need to become learning guides. Therefore, if prospective teachers are to be expected to use PBL as soon as they become teachers, they should learn through PBL while they are students. This would require a big change in the way they are accustomed to behave in school and university – they would need to move from being listeners to being active learners. The point is whether or not they feel like becoming protagonists of such an enterprise.

Objectives

This paper aims to analyse prospective physical sciences teachers' (PTs') reactions towards learning about how to use the laboratory for science teaching through problem-based learning.

Theoretical Background

From the PBL concept to its role in science education

Problems can play three different roles in the teaching and learning processes (Dumas-Carré and Goffard 1997, Watts 1991), as they can be used:

- To evaluate students' learning, being solved after teaching and learning;
- To deepen students' learning, being solved during the teaching and learning processes;
- As a starting point for teaching and learning, being given to the students or formulated by themselves at the very beginning of the teaching and learning processes.

When problems play the role mentioned in the last place it is usual to say that Problem-Based Learning (PBL) is taking place. However, this newer role of problems has been conceptualized in several different ways (Savin-Baden and Major 2004), ranging from teacher-centred use of problems to teach (e.g., lecture-based cases and case-based lectures) to student-centred use of problems to learn. The latter way of using problems is the one that earns most consensus among science educators as having to do with PBL (Chin and Chia 2004, Evensen and Hmelo 2000, Gandra 2001, Hmelo-Silver 2004, Lambros 2002, Leite and Afonso 2001, Leite and Esteves 2005, Savin-Baden and Major 2004). PBL assumes that students can "learn by doing" and therefore acknowledges that they play an active role in learning (Barron et al. 1998). Usually, PBL is carried out in small groups, as it is believed that collaboration between students increases the chance of success and enables the development of communication and interpersonal relationship skills (Lambros 2004). Transferring Barrow's (quoted by Yeung et al. 2003) primary educational objectives that can be addressed by PBL in the clinical context to the science education context, it can be argued that PBL can promote the development of effective reasoning, the organisation of a knowledge base for

use in science education contexts, the development of effective self-directed learning skills and an increased motivation for learning science. Thus, PBL is not only a way of learning but also a way of learning about learning and a way of promoting lifelong learning (Hmelo-Silver 2004) as well as a way of developing self-directed learning skills (Yeung et al. 2003; Tan, 2004). In addition, if PBL is organised in such a way as to start with everyday problems, which are multidisciplinary by nature, than it can facilitate knowledge integration and contribute to equip citizens to face socio-scientific problems better in their daily lives (Barron et al. 1998, Nagel 1996, Savin-Baden 2000, Yeung et al. 2003).

Learning through PBL

In PBL as well as in daily life, problems appear at the beginning, that is, before having a solution and even before being aware of what is needed for the solution. To solve a problem, both students and citizens would have to make a journey from the known to the unknown, relying on their previous knowledge but at the same time feeling the need to develop it in order to overcome successfully the challenge presented by the problem. Thus, during this process they will develop their knowledge competency, as they will acquire comprehension of the scientific concepts and principles that underlie the problem to be solved. In addition, they will enlarge their repertoire of general competencies, as procedural knowledge, reasoning and communication are also required during the problem-solving process (Lambros 2002, Lambros 2004). "In PBL, the content of a problem serves as a major vehicle that influences each student's direction and motivation to learning" (Yeung et al. 2003, 341).

An analysis of the literature (e.g. Albanese and Mitchell 1993, Barrows and Tamblyn 1980, Davis and Harden 1999, Gandra 2001, Lambros 2002, Leite and Afonso 2001) leads to the conclusion that a PBL sequence can be structured around four phases. During the first phase, the teacher selects a scenario or problem context believed to lead students to raise problems that are both motivating to them and relevant from the curriculum point of view. The context should deal with a problem situation as realistic as possible and it can be presented to the students through a videotape, an audiotape, a text, etc. (Davis and Harden 1999, Lambros 2002, Lambros 2004).

In the second phase, students are faced with the scenario or problem context and, in small groups, they are asked to formulate questions focusing on: "What issues/concepts am I already familiar with?"; "What are the issues/concepts I do not know anything about?"; "What are the issues/concepts that I do not understand?"; "What have I never heard about?"; and "What would I like to know about this?"; "What would I like to develop further?"; Afterwards, students are asked to discuss the questions formulated, to analyse their relevance and interdependency and to place in a logical order the relevant questions – problems – to be solved.

The third phase is devoted to finding out solutions for the problems. In order to devise a strategy, students have to answer questions like "what do I already know about this problem?"; "What do I need to do to solve this problem efficiently?"; and "What sources of information should I use to find out an appropriate solution?"; Afterwards they have to put the strategy into practice, using whatever resources they feel that can be useful to carry out the task successfully. When students reach solutions for a problem or solutions for a set of problems that were worked on together, the solutions found should be presented to the whole class. Finally, the teacher should promote a global analysis of the process (fourth phase) aiming at synthesising learning and analysing the contribution of the process followed to both science education and education

for citizenship. Questions like "What did I learn?"; "What was not fully understood?"; and "What sorts of strategies and behaviours worked better?"; can be addressed. Thus, the role of the teacher is to create conditions for students to learn and to help them to become aware of the successes and failures of the learning process.

PBL and teacher education

How teaching is approached affects the way students learn (Yeung et al. 2003). PBL requires teachers to move from teacher-centred teaching approaches to student-centred learning approaches. Thus, if PBL is to lead to effective learning, teachers need to be equipped with competencies of process skills (such as handling group dynamics, questioning skills, facilitating meta-cognition etc.) and to be able to identify, articulate and assess those skills (Tan 2004).

There is some empirical evidence that preservice teachers actively construct beliefs through teaching experiences and that learning about teaching is best accomplished by direct experience of the teacher-learner and by opportunities to analyse that experience critically (Honcock and Gallard 2004). Thus, PBL offers teacher educators an important vehicle that exposes their own students (preservice teachers) to situations they are likely to face when they become teachers (Edwards and Hammer 2004). As there is some empirical evidence that PBL can assist students in learning concepts and also in working with others (Murray-Harvey and Slee 2000), it can be argued that prospective teachers should "be taught" by PBL in science methods courses, so that they learn important concepts, get used to working with others and perceive the relevance and the viability of the teaching approach. Dalghren *et al.* (1998) analysed the integration of environmental education in teacher training through PBL. Data collected from seven teachers reveal different ways of conceiving PBL and the role of the teacher. The latter were found to range from supportive to directive, the former being more compatible with PBL than the latter. Edwards and Hammer (2004) conducted a research study with 54 Australian preservice teachers that required them to learn the unit Child Development through PBL. The results of the study indicate that a few students found it hard to understand what they were asked to do and had problems in working with other people. However, the majority of the participants found learning realistic and empowering for them as students and future teachers. According to Dalghren *et al.* (1998), "the implementation of PBL is more than a change of methods, it requires reflections on the part of the teachers on their conceptions of knowledge and learning" (446).

Research methodology

Sample

A group of 38 prospective Physical Sciences teachers attending the fourth year of a five-year-long undergraduate teacher education programme participated in the study. They represent 100% of the PTs that were taking a course on Methodologies of Teaching Physics and Chemistry that was taught by the authors. The majority of the PTs were about 21 or 22 years old and they were attending the course for the first time. Despite the fact that a few experiences on active learning already exist at the University of Minho (namely at the School of Health Sciences), PTs enrolled in this study had a single short experience of learning through PBL within this same course (Leite and Esteves 2005).

Teaching methodology

Subjects were invited to watch a video clip on a science teachers' meeting ("What a confusion!..."). The four science teachers were

having a discussion about the issue of using the laboratory for teaching. The discussion was taking place in a classroom and the teachers were talking about the concept, role, varieties and evaluation of laboratory activities. During the discussion the teachers put forwards ideas on these issues without reaching any conclusion. After watching the video, PTs were organized in small groups and asked to formulate questions that were suggested to them by the video. Afterwards, each group presented the questions to the whole class so that they could be clarified and discussed with two purposes: avoiding repetitions and finding out possible interdependencies of the relevant questions. Then, four groups of questions were organized by the PTs together with one of the authors: the first group of questions deals with concepts, role and practical utility of different types of laboratory activities; the second one focuses on the structure and use of lab worksheets; the third one concentrates on the performance of lab activities, in general, and on the implementation of lab procedures, in particular; the fourth one focuses on the evaluation of students' learning from laboratory activities and on the pedagogical role of lab reports. Afterwards, PTs were asked to find out answers for each group of questions, following the sequence given above. This job was carried out in small groups (four or five members) and PTs were invited to look for information sources to carry out this job. However, a variety of materials (like books, papers, dissertations, textbooks, etc.) were made available to the PTs. An oral presentation (followed by class discussion) by each work group was expected after reaching answers to each group of questions. Then, a global analysis of the learning that had taken place during the module as well as of the teaching methodologies adopted was carried out.

Data collection

Data were collected by means of a questionnaire, focusing on PTs' opinions on PBL, and through a videotape on PTs' discussion and evaluation of the whole approach. The questionnaire used is an improved version of the one mentioned in Leite & Esteves (2005) that includes open and closed questions.

Data analysis

As far as students' answers to closed questions are concerned, frequency per category of answer was calculated. Answers to open questions as well as the videotape were content analysed in order to find out the main issues pointed out by the PTs.

Presentation and discussion of results

PTs were asked about positive and negative aspects of the set of classes within the scope of this module of the course on Methodologies of Teaching Physics and Chemistry. As far as positive aspects are concerned, PTs pointed out aspects related to students' role, teacher's role and types of activities carried out (table 1). Only one PT mentioned learning explicitly. Twelve PTs stated explicitly that they valued the fact that they were asked to play a more active role than they were used to in other classes while six PTs enjoyed the fact that the teacher played a passive role, as there were no lecturers. In the final discussion subjects pointed out that although the teacher played a passive role, they nevertheless felt that she was always there, "keeping them on the track", and giving them the necessary guidance to avoid time waste or insecurity feelings. These changes of roles are taken as necessary conditions for PBL to succeed (Yeung *et al.*, 2003). The activities enjoyed by larger numbers of PTs are problem solving and small group work which are typical PBL activities (Davis & Harden, 1999; Lambros, 2004; Watts, 1991). The final discussion revealed that PTs enjoyed solving the problems because they focus on a

resource – the lab – that is familiar to them and about which they feel curious.

Table 1: Positive aspects pointed out by the PTs (N=38)

Dimensions	Positive aspects	f
Students' role	Students' active role	12
Teacher's role	Teacher's passive role	6
Types of activities	Problem-solving activities	11
	Small group work	10
	Discussion between work groups	3
	Video watching	3
	Question formulation and organization	2
Learning	Learning promotion through group work	1
No answer		3

The negative aspects mentioned by the PTs when answering to the questionnaire are mainly related to the tasks performed and to the workload (table 2).

Table 2: Negative aspects pointed out by the PTs (N=38)

Dimensions	Negative aspects	f
Tasks performed	Presentation of answer to problems	23
	Information search	6
Workload	Work after the classes	3
	Workload in the classes	2
Time available	Impossible to explore related issues	1
No negative aspect		1
No answer		3

The majority of the subjects (n=23) felt that the way the answers to the problems formulated by themselves was presented to the whole class was boring and repetitive. In fact, all the groups worked on the same problems and were asked to present their answers to their counterparts, meaning that PTs had to hear basically the same answer several times. In the final discussion, they suggested that different groups should present the answers to different problems. However, they showed a fear that the groups could invest differently in the problems, depending on whether or not they were asked to present its solution to the class. This result means that other ways of presenting results from PBL work, suggested by authors like Davis & Harden (1991) and Lambros (2002; 2004), are to be taken seriously. A few PTs (n=6) did not enjoy doing bibliographic search. This result was not surprising, as there is some evidence that students do not enjoy reading. A few PTs also pointed out that the teaching approach used in the module led to an extra workload both in the classroom (n=2) and outside it (n=3). However, in the final discussion the majority of the participants in the study argued that the extra work was useful, as they feel better prepared than usual for the final exam. One PT mentioned that the time dedicated to the study of this module was not enough to explore and to deepen issues related to it. Another PT stated that he/she found no negative aspect on the set of classes dedicated to the module.

Table 3 shows that the majority of the PTs felt that the contents belonging to this module were approached at a normal level, that is at a similar level of deepness as the contents within the scope of other modules. However, about one third of the subjects stated that they were approached at a deeper level. According to the PTs, the use of diverse bibliographic sources and the teaching strategies adopted are the main factors responsible for it. In the final discussion, the majority of the PTs mentioned that they learned not only the content related to the problems but also about where they should look for information if they feel like going more deeply into these issues.

Table 3: Level of approaching the contents (N=38)

Level	f
Very superficial	0
Superficial	0
Normal	22
Deep	14
Very deep	0
No answer	2

The majority of the PTs did not report any difficulty or lack of competency when working on this module (table 4). However, a few subjects (n=7) mentioned that they become aware of their lack of knowledge about lab work, that is, about the topic of the module. Other difficulties mentioned are related to the location and use of information sources and to doing group work. In the final discussion, a few PTs mentioned that during the classes dedicated to the module, they overcame their initial difficulties in dealing with several sources at the same time. It is worth noticing that learning about learning was a result of PBL reported by Hmelo-Silver (2004).

Table 4: Difficulties or lack of competency felt by the PTs (N=38)

Aspect	Difficulties/lack of competency	f
Content to be learned	Lack of knowledge of lab work	7
Use of information sources	Lack of competency for doing synthesis of information	4
	Difficulty in locating relevant bibliographic sources	3
	Lack of autonomy for doing bibliographic search	1
Group work	Uncomfortable with group work	1
	Dislike group work	1
No difficulty/lack of competency		23

As far as subjects' learning about how to behave as students is concerned, 11 PTs stated that they did not learn anything, two did not answer the question and five gave non-understandable answers (table 5). These results may mean that about half of the participants either did not understand the question or were already feeling competent learners. The rest of the participants mentioned that they learned how to use information sources, how to manage learning conditions, how to communicate and how to deal with issues related to the laboratory. It is worth noticing that the first three aspects concern general competences that are not dependent on the content of the module under question. The last aspect is related to specific competencies that are dependent on the content of the module. These results are consistent with expectations from works by authors like Barron et al. (1998), Lambros (2004), Tan (2004) and Yeung et al. (2003).

Table 5: Learning on how to behave as a student (N=38)

Aspect	Learning	f
Information sources	To look for information	4
	To select relevant information	2
	To synthesize information	4
Content to be learned	To become aware of how to use lab worksheets	4
	To become aware of how lab activities should be evaluated	4
Learning conditions	To feel compelled to learn	2
	To manage time	1
	To become autonomous in problem solving	1
Communication	To feel confident when exposing one's own ideas	2
	To prepare powerpoint presentations	1
No learning carried out		11
Non-understandable answers		5
No answer		2

PTs were also asked about what they think they learned about the way they should behave in the future, as soon as they become teachers. Table 6 reveals that the participants in the study show a variety of opinions, as could be expected from previous studies (e.g. Edwards and Hammer 2004).

Table 6: Learning on how to behave as a teacher (N=38)

Aspect	Learning	f
Content approached	How to use lab work in different ways	16
	How to diversify ways of evaluating students' learning in the lab	8
Teacher's specific behaviours	How to guide students when solving problems	3
	How to use small group work	3
	How to give students a more active role	2
	How to value the process of learning	1
Teacher's general behaviours	Need to diversify the teaching methods	1
	Need to manage time	1
	Need to look for lab materials	1
	Need to prepare classes in advance	1
No learning		4

PTs' answers focused on the content of the module and on teacher's behaviour. In the former case the emphasis is on differentiation and it may mean that they realised that, opposite to what often happens at the university level (Dourado 2005, Oliveira 2001), laboratory activities can be structured and evaluated in diverse ways. During the final discussion a few PTs even mentioned that the diversity of ways of using lab activities is in contrast with what their school teachers and university professors were accustomed to do. In the latter case the emphasis is on both specific and general teacher's behaviours. Specific teacher's behaviours mentioned by the PTs relate to the use of teaching strategies and teacher's behaviours that were shown during the teaching of the module. General teaching behaviours relate to some generalisations that PTs seem to have drawn from the way this module was approached.

As far as time and material conditions created by the teacher for PTs to learn about this module is concerned, the participants in the study seem to feel quite happy with them (table 7). In fact, the majority of the PTs rated them as good and a few even rated them as very good. However, about one fourth of the participants rated the quantity of information sources available and the classes dedicated to the module as "moderate". In the former case, this rating may be due to the fact that it was hard for the PTs to learn on how to use the large variety of sources available. In the latter case, the result may be due to the fact that some students would like to have more time to spend on the preparation or reorganization of lab worksheets. However, the final discussion revealed that PTs enjoyed finding the same ideas in different sources. Some of them explicitly stated that this made them feel that they could trust their answers. In addition one or two students rated as "poor" a few items used to evaluate their global satisfaction with the learning conditions. It should be noticed that these PTs had already got a job and gained special status enabling them to miss some classes. However, in this module they were asked to come to work on the problems in their free times.

Table 7: PTs' satisfaction with the learning conditions (N =38)

Aspect	Level					
	No answer	Bad	Poor	Mode-rate	Good	Very good
Teacher's motivation of the students	1	0	2	8	24	3
Quantity of the information sources available	1	0	1	10	22	4
Quality of the information sources available	0	0	0	6	29	3
Number of classes dedicated to the module	1	0	2	11	21	3

The different availability of the members of the group seems to have interfered with the group work, leading seven PTs to state that their groups did not work as such. As expected (Davis and Harden 1991, Lambros 2004, Watt 1991), the other 31 PTs stated that their groups worked well. During the final discussion, PTs mentioned that small group work was important to facilitate their job. Otherwise, they believe that the teaching approach put into practice would turn learning into a too hard and unrewarding task for them.

Conclusions and Implications

Results indicate that prospective teachers enjoyed the new way of learning and felt that they developed content knowledge and social and meta-cognitive competences. The fact that prospective teachers showed positive reactions towards PBL suggests that teaching through PBL should be used further at the university level. However, enjoying PBL is not necessarily the same as learning through PBL. On the one hand, the fact that PTs enjoyed PBL does not mean that PBL is better for content learning and problem solving competences development than other teaching strategies. On the other hand, using PBL in initial teacher education programmes offers no guarantee that in their future as teachers PTs will use PBL in their own school teaching. Hence, research on the efficacy of PBL for university learning as well as for teaching in schools is needed, so that a decision on whether or not it is worthwhile changing the teaching methodology used at university, namely for university methods courses, can be taken.

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