The Relationship Between Conceptions of Teaching and Learning and Perceptions of Problem-Based Learning among Physics Faculty

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Abstract

This paper presents findings from research that examined the relationship between physics faculty conceptions of teaching and learning and their perceptions of problem-based learning as an appropriate pedagogical approach in physics education. The introduction of problem-based learning in physics is often met by significant resistance and opposition. One of the reasons often cited for this opposition, is epistemological beliefs, and hence conceptions of teaching and learning, of the physics educators that are not aligned to student-centered learning. This paper examines these conceptions and discusses the implications for the use of problem-based learning in physics education.

Keywords: Conception of teaching and learning, physics, phenomenography

1. Introduction

Although problem-based learning (PBL) is now widely used as an educational approach in many different disciplines its use in physics education is a relatively recent development (Walsh et al., 2007). Although, research has shown the benefits of the student-centred and constructivist nature of PBL there appears to be a reluctance to introduce PBL into physics courses. This is possibly due to the pedagogical view that the students require a sound body of knowledge and mathematical skills before they are equipped to engage with a problem-solving process (Bowe and Cowan, 2004). Within the PBL environment it is through group-based problem-solving activities that the students develop their knowledge and conceptual understanding. Hence, it can be seen as the exact opposite of the traditional pedagogical approaches found in most science courses, where the knowledge is given before the students have opportunities to apply and problem solve. If PBL is to be widely implemented in physics education, it has to be widely adopted by physics lecturers. However, as Kember (1997) and Kandlbinder and Mauffette (2001) reported, successfully adopting the PBL approach requires lecturers having student-centred conceptions of teaching whereby teaching is viewed as a means of facilitating understanding and conceptual change and development. Savin-Baden's (2003) research also highlights the importance of the lecturers' epistemological perspectives in determining the model of PBL. O'Grady (2004) argued that educators must not ignore the difficult yet fundamental epistemological questions that underpin PBL. Failing to do so can lead to a model of PBL which is not student-centred and hence does not achieve the potential benefits of a group-based problem-driven learning environment. Research by Ramsden (1991) that examined the differences in teaching approaches between various disciplines revealed that science lecturers are more likely to use formal, didactic teaching methodologies and that they are less open in their attitudes towards student learning. In addition, research by Trigwell et al. (1999) revealed that those who conceive of teaching as transmitting information to students would see little use in posing problems for students to comprehend. Finally, in research by Ching and DeGallow (2002) it is argued that in order to successfully adopt PBL, lecturers not only need to be enthusiastic but they also must show willingness to fundamentally change their teaching practices.

In short, for lecturers to adopt PBL they need to be enthusiastic, willing to change their teaching practices and have a student-centered conception of teaching but unfortunately, research has shown that many science lecturers tend not to have the necessary student-centered conception of teaching (Ramsden, 1991b). Therefore, in order to make informed decisions to introduce PBL, and if so to what extent and what model, requires being able to determine lecturers' conceptions of learning and teaching and knowing how these, and other factors, will determine their teaching approaches. This research examined the conceptions of teaching and learning of physics faculty in departments where PBL courses had been introduced and investigated the relationship between these conceptions and their perceptions of PBL. The implications these findings have for the use of PBL in physics education is discussed.

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2. Conception of Teaching and Learning

In one of the earliest studies of lecturers' conceptions of teaching from the student learning perspective, Dall'Alba (1991) interviewed 20 teachers from the fields of economics, English, medicine and physics in Australian universities. She identified seven different ways in which those teachers conceived of or understood their teaching in their particular teaching and learning situations:

1. Teaching as presenting information;
2. Teaching as transmitting information (from teacher to students);
3. Teaching as illustrating the application of theory to practice;
4. Teaching as developing concepts / principles and their relations;
5. Teaching as developing the capacity to be expert;
6. Teaching as exploring ways of understanding from different perspectives;
7. Teaching as bringing about conceptual change.

Martin and Ramsden (1993) later suggested that the more complete conceptions are associated with a lecturer whose awareness has been expanded to not only include himself/herself but also the students' understanding of the content. Research carried out by Prosser et al. (1994) identified six conceptions of teaching:

1. Teaching as transmitting concepts of the syllabus;
2. Teaching as transmitting the teacher's knowledge;
3. Teaching as helping students acquire concepts of the syllabus;
4. Teaching as helping students acquire teacher's knowledge;
5. Teaching as helping students develop conceptions;
6. Teaching as helping students change conceptions

In research by Linder and Marshall (2003) three conceptions were characterized among physics lecturers who saw the purpose of their teaching as:

1. The promotion of metacognition as a way of exploring conceptual understanding;
2. The transfer of theoretical content as a framework for learning to successfully solve physics problems;
3. The promotion of a coherent view of content as a way of avoiding an "applied mathematics approach".

Prosser et al. (1994) also identified five conceptions of learning:

1. Learning as accumulating information to satisfy external demands;
2. Learning as acquiring concepts to satisfy external demands;
3. Learning as acquiring concepts to satisfy internal demands;
4. Learning as conceptual development to satisfy internal demands;
5. Learning as conceptual change to satisfy internal demands.

Their research revealed that teachers who hold a conception of teaching as the transmission of information, with little or no focus on the students or their understanding, also hold a conception of learning as students accumulating more information rather than developing and changing their conceptions and understanding. Similarly, teachers who hold the more complete conceptions of teaching also hold a more complex understanding of learning.

Trigwell et al. (1994) carried out research to examine the variations in the way lecturers approach their teaching. They identified five different approaches to teaching, which were constituted in terms of the teachers' intentions and strategies:

1. A teacher-focused strategy with the intention of transmitting information to students;
2. A teacher-focused strategy with the intention that students acquire the concepts of the discipline;
3. A teacher-student interaction strategy with the intention that students acquire the concepts of the discipline;
4. A student-focused strategy aimed at students developing their conceptions;
5. A student-focused strategy aimed at students changing their conceptions.

Trigwell and Prosser (1999) went on to relate these five approaches to teaching to the lecturers conceptions of teaching and learning. They showed that teachers who adopted a student-focused approach to their teaching of a topic conceived of their teaching and learning in more complete ways, for instance as conceptual change and development. Teachers who approached their teaching from a teacher-focused perspective conceived of their teaching and their students learning in less complete ways, for instance as information transmission.

3. Research Methodology

The research is situated in a set of epistemological beliefs and assumptions termed "constitutionalism" (Marton and Booth, 1997), which is similar to the more commonly known constructivist perspective in that they both view meaning as something that is not discovered, but constructed. Trigwell and Prosser (1996) argue that this perspective is the most appropriate from which to situate research that examines students' or teachers' conceptions of teaching and learning. Students and teachers will not all experience the same learning and teaching situation in the same way nor will they approach their learning or teaching in the same way, even within the same context. From this constitutionist perspective, I chose a phenomenographic research methodology that would serve as a framework in which I could investigate physics lecturers' conceptions of learning and teaching, approaches to teaching, and their perceptions of PBL as a pedagogical approach. Phenomenography is an empirical research methodology that was designed to answer questions about thinking and learning, especially in the context of education research (Marton, 1986). It is concerned with the relationships that people have with the world around them and aims to elucidate the different possible conceptions that people have for a given phenomenon. In the phenomenographic approach the objective is to find out the qualitatively different ways of experiencing or thinking about the same phenomena. It assumes that there are a limited number of qualitatively different ways in which different people experience a certain phenomenon (Marton, 1994). These are then characterised in terms of categories of description, related to each other and forming hierarchies in relation to a set of criteria – "outcome spaces".

3.1. Data Collection & Analysis Methods

Although different research methods have been used in the phenomenographic methodology, the dominating method has been the open and deep interview, which is carried out in a dialogical manner (Booth, 1997). In order to choose the interview participants, the physics lecturers were asked to complete the Approaches to Teaching Inventory (ATI). Prosser and Trigwell (1999) developed the ATI as an instrument to "measure the ways teachers approach their teaching" (p.176) in a particular context. It evolved from their phenomenographic research (Prosser et al., 1994; Trigwell et al., 1994) and therefore, in a sense, it already assumes the categories within the outcome space. The inventory examines whether a lecturer teaches, or at least intends to teach, for conceptual change or information transmission and whether that lecturer adopts a student-focused or a teacher-focused approach in a particular context. In the research presented in this paper, each physics lecturer completed at least one inventory but in a number of cases they completed two, as the responses to the inventory are relational and specific to the context. The aim of the interviews was then to have the participant reflect on his or her experiences and then relate those experiences to me in such a way that both of us came to a mutual understanding about the meanings of the experiences, or of the accounts of the experiences. In a sense the interviews also provided me with the opportunity to ask follow-up questions from the ATI. Without the interviews, I would not have had access to the lecturers' conceptions, perceptions and understanding, which only emerged from the extensive interview discussions. During data analysis, I sought to identify qualitatively distinct categories that described the lecturers' perceptions, conceptions and approaches. I believed that a limited number of categories were possible for each research question and that these categories would be discovered by immersion in the data. I examined the transcripts of the participants' interviews, looking both for similarities and differences among them. In this process, I developed initial categories that described their experiences, concepts and experiences of the different phenomenon. I developed an outcome space, for each topic while ensuring internal consistency and parsimony. Once I had defined the stable outcome spaces I then considered how the individual categories relate to each other and how the outcomes spaces relate to each other.

3.2. Research Participants

In all 31 physics lecturers from two higher education institutes participated in this research. In these institutes, the PBL elements were extensive and there were proposals to increase its use further.. To ensure reliability in the findings, I felt it was necessary to involve as many lecturers as possible and to ensure there were a variety of profiles. There were 6 PBL tutors among the 31 physics lecturers and 8 lecturers who were openly opposed to the introduction of PBL. The conceptions and perceptions of 15 of these physics lecturers were examined in interviews. The lecturers were selected, after the ATI data were analyzed, to include a range of profiles, as shown in Table 1.

Table 1. Number of lecturers interviewed in each sub-scale of the Approaches to Teaching Inventory

Sub-scales	Student-focused	Teacher-focused	Unclear Strategy	TOTALS
Conceptual Change	3	0	2	5
Information Transmission	0	3	2	5
Unclear Intention	0	3	2	5

TOTALS	3	6	6	15

4. Findings

4.1. Conceptions of Teaching

The analysis of the interview data revealed that physics lecturers appear to hold qualitatively different conceptions of teaching. It also revealed that a lecturer might hold a conception of teaching in one environment and a different conception in another. However, it was the lecturers' predominant conceptions of teaching in lecture-based courses (including lectures, tutorials and laboratories) that were examined or to be more specific the lecturers were questioned about the purpose of their teaching. An outcome space emerged from analysis of the data that describes 4 different ways in which the physics lecturers conceived of their teaching in lecture-based courses, as summarized in Table 2. The numbers in the brackets in Table 2 represent the number of lecturers in that category who are either PBL tutors (PBL) or who are opposed to the use of PBL (Opp.).

Table 2. Outcome space that describes the different ways lecturers conceive of teaching in lecture courses

	Categories of Conceptions of Teaching	Number of Lecturers	
A	Teaching as presenting the correct information (facts, equations, knowledge) necessary to prepare the students for assessments and the workplace	**6**	(4 Opp.)
B	Teaching as transmitting the information in order for the students to develop conceptual understanding and problem-solving skills at a later stage	**4**	(1 PBL)
C	Teaching as explaining the lecturer's knowledge and understanding in order that the students can develop an understanding of physics and problem-solving skills	**3**	(1 PBL)
D	Teaching as providing the students with opportunities to develop conceptual understanding and problem-solving skills	**2**	(2 PBL)

Lecturers in Category B hold a very similar conception of teaching as those in Category A, in that they both see teaching as presenting, or transmitting, the information to the students. However the lecturers in Category B transmit this information to their students so that they can develop conceptual understanding and problem-solving skills at a later stage. There is disagreement on exactly when this stage is, as some felt this would happen in later stages of the course and others felt this happened in the workplace. However, they agreed it was not their responsibility and was therefore not the purpose of their teaching. Lecturers in Category C view the purpose of teaching as helping the students develop an understanding of physics and problem-solving skills but they feel this can be achieved by explaining their knowledge and understanding to the students. Therefore, although categories A, B and C differ in purpose, they are all essentially teacher-focused conceptions of teaching that emphasis presenting, transmitting and explaining information and knowledge. Lecturers in Category D conceive of teaching in a more student-focused way, in that they view the purpose of teaching as providing the students with opportunities to develop conceptual understanding, problem-solving skills and laboratory skills. It is interesting to note that only 2 of the 4 PBL tutors saw the purpose of teaching as providing the students with these opportunities. However, when asked about the purpose of teaching in their PBL courses, all 4 tutors fall into Category D, using words such as "facilitate", "guide" and "tutor" to describe their teaching approach. One tutor suggested a reason for this change of approach:

> "It is not that I go in (to the PBL tutorial) consciously thinking about developing their conceptual understanding, it is just what happens because the system is set up to support this type of learning…The PBL process, small groups, interesting problems, it is not like I decide not to give a lecture, it just wouldn't be appropriate in that situation. Just as PBL is not appropriate when I have to teach 60 first year students, on my own, in a lecture hall."

From the analysis of their conceptions of teaching, it was possible to make the following points:

- The majority of physics lecturers interviewed conceive of teaching primarily as a way of transmitting, presenting, explaining and demonstrating the correct information, theory, knowledge or understanding;
- A small minority conceive of teaching as a means of providing the students with opportunities to develop conceptual understanding and problem-solving skills;
- Teacher-focused conceptions of teaching are strongly related to prioritizing content coverage when designing lessons;
- All 4 lecturers opposed to the use of PBL hold teacher-focused conceptions of teaching (presenting/demonstrating) and see content coverage as the priority;

4.2. Conceptions of Learning

Table 3 shows the outcome space that describes the two different ways in which the physics lecturers conceive of their students' learning.

Table 3. Outcome space that describes the two different ways lecturers conceive of their students' learning.

	Categories of Conceptions of Learning	Number of Lecturers	
A	Learning as the accumulation of facts, theories, principles and skills as demonstrated, presented and explained by the lecturer	**10**	(1 PBL, 4 Opp.)
B	Learning as the development of an understanding of the conceptual nature of physics	**5**	(3 PBL)

In the interviews, the lecturers were also asked about their students' approaches to learning and specifically what they perceive as the factors that affect their students' approaches to learning. First, the lecturers were asked to describe the approaches to learning they perceive their students adopt. Table 4 shows the three different categories of perceptions: a number of lecturers described an approach that can be described as a 'surface' approach, while others described an approach that can be described as a 'deep' approach and there were also a number of lecturers who had no perception of the their students' approaches to learning.

Table 4. Outcome space that describes the approaches to learning the lecturers perceive their students adopt.

	Categories of Perceptions of Student Approaches to Learning	Number of Lecturers	
A	Students adopt a surface approach	**4**	(1 PBL)
B	Students adopt a deep approach	**8**	(3 PBL, 2 Opp.)
C	Have no perception of what approach their students take	**3**	(2 Opp.)

Of the 8 lecturers who feel their students adopt a deep approach, 5 conceived of learning as the development of an understanding of the conceptual nature of physics and felt this could only be achieved if the students adopted a deep approach. However, for 2 of these 5 lecturers there was a distinct lack of understanding of the affects many aspects of the learning environment have on their students' approaches to learning. This lack of understanding was also prevalent among the other 3 lecturers who perceived their students as 'deep' learners but conceived of learning as the accumulation of information. From the analysis of their conceptions of learning, it was possible to make the following points:

- The majority of these physics lecturers view learning as accumulating knowledge with a minority viewing learning as the development of conceptual understanding;
- The lecturers opposed to PBL view learning as the accumulation of knowledge and all but one of the PBL tutors see learning as the development of conceptual understanding;
- The majority of lecturers feel that their students adopt a deep approach to their learning but half of these lecturers did not see assessment as playing a major role in determining the students' approaches to learning;
- The majority of lectures perceive the nature and relevance of the course material as having a greater role than assessment in determining their students' approaches to learning.

4.3. Perceptions of Problem-based Learning

The interviews examined the lecturers' perceptions of PBL as a pedagogical approach in physics education. There was a wide range of perceptions as attitudes PBL varied from enthusiasm to tolerance to opposition. In the analysis I initially excluded the perceptions of the PBL tutors and organized the remaining perceptions into three categories: positive, negative and neutral. Table 6 shows these categories with the perceptions in each and it should be noted that a lecturer may be opposed to the introduction of PBL but may still have positive perceptions of it. For instance, a lecturer may feel PBL has pedagogical benefits but may also feel that it is far too resource intensive. Equally, a lecturer who is supportive of PBL may also have some negative perceptions. The perception that PBL requires much more work by the lecturer and more resources was prevalent among both the physics lecturers who supported the use of PBL and those against it. For instance, Lecturer W who was not a PBL tutor but supported the use of it in physics education stated:

> "I like the idea of using PBL, it seems to mirror the research learning process. We all know that students learn more doing their final year project than in all the previous years but I just do not have the time to redesign my course. I'm not going to do it unless I can do it properly and my current research commitments do not make that possible."

Table 6. Outcome space that describes the different ways lecturers perceive of PBL

Category	Perception
Positive	• It is a student-centred approach that supports the development of conceptual understanding, problem solving skills and other key skills • It models the learning that occurs in the research process and it is therefore more effective than passive learning
Negative	• It is not a suitable approach for the physical sciences, as they are conceptual subjects that cannot be taught through this approach • It slows the learning process and therefore it is not possible to cover the required and necessary content • It is only suitable for developing problem-solving skills with students who already have the required knowledge • It concentrates more on the development of skills that are not necessary to be a physicist • It requires far too many resources and too much effort on the part of the lecturers • It is just the current fad and will not last
Neutral	• It is a better approach than the traditional approach but it requires extra resources and effort • It predominantly works because of the social dimension but it would be less resource intensive to simply introduce more group activities • It requires far too much work and resources and therefore its use will fade out

There was also a mistrust of the approach due to the fact that it is a 'new' approach and hence there was little evidence of its benefits. From those opposed to the use of PBL in physics education, the following quotes were typical:

> "It is not my job to worry about group, communication, presentation skills and so on. My job is to teach physics, the students come here to learn about physics. I think we are forgetting what we are here to do."

> "If we can't cover 100% of the curriculum using PBL, then we shouldn't even be contemplating using it. We are just making everything easier for the students. from the style menu. Insert your heading text and choose the appropriate heading level from the style menu."

4.3.1. Tutors' Perceptions of PBL

The PBL tutors' perceptions were also examined. Their perceptions were relational, in that the tutors tended to compare the PBL approach to a traditional lecture-based course. For instance, it can be seen from Table 7 that the tutors perceive PBL as requiring extra staff time, along with other additional resources, such as laboratory equipment and adequate learning resources. Indeed, all tutors felt that there are extra resources needed to run the PBL course as compared to a course taught in a traditional format, in particular time and equipment.

Table 7. Outcome space that describes the different ways tutors perceive of PBL

Category	Perception
Positive	• It is a student-centred approach that supports the development of conceptual understanding, problem solving skills and other key skills • It models the learning that occurs in the research process and it is therefore more effective than passive learning • It supports the development of key skills • It is much more enjoyable than lecturing • It allows the tutors to observe the learning process
Negative	• It requires a great deal of extra time, particularly in the development stage, but also to assess and to give feedback • It is not feasible with large numbers

4.4. Relationships between the conceptions of teaching and learning and perceptions of PBL as a pedagogical approach in physics education

The findings from this study revealed that the majority of lecturers held both positive and negative perceptions of PBL. The research revealed that there are a small minority of lecturers adamantly opposed to PBL and only hold negative perceptions of it as a pedagogical approach in physics education. There are an approximately equal number of lecturers who are fully supportive of it and hold predominantly positive perceptions. The remaining lecturers tend to have mixed perceptions and see its potential benefits while at the same time recognizing its disadvantages. For instance, many of these lecturers see its pedagogical advantages but see it as impractical in terms of resources and time. Table 8 summarizes the findings from the outcome spaces. Those lecturers who believe that the purpose of teaching is to transmit information feel PBL is a waste of resources, inefficient and totally unnecessary. Categories C and D may also include lecturers opposed to PBL but the reasons tend to be associated with time and resources and the fear that committing to such an initiative would take from their other interests and activities.

Table 8. Summary of Findings aligned the outcomes spaces

Cat.	Conception of teaching	Conception of learning	Teaching Approach	Environment Affects Approach	Perception of PBL
A	Facilitating learning	Development of conceptual understanding	Student-focused	No	Positive
B	Transmitting information	Accumulation of knowledge	Teacher-focused	No	Negative
C	Facilitating learning	Development of conceptual understanding	No clear approach or teacher-focused	Yes	Mixed
D	Changes depending on teaching context	Changes depending on teaching context	No clear approach or teacher-focused	Yes	Mixed

The lecturers involved in this research study came from two higher education institutes where PBL had been introduced into physics education. In each institute it was introduced by a small number of 'early adopters' (from Category A in Table 8) and there has been a minority of lecturers opposed to the use of PBL (from Category B). However, the lecturers involved in the PBL courses have sought to persuade their remaining colleagues (categories C and D) to get involved in the PBL courses. These lecturers may adopt predominantly teacher-centred approaches but there may be strategies that can be used to persuade them to move towards more student-centred approaches. From the study of the physics lecturers' teaching approaches, conceptions of teaching and learning and their perceptions of PBL, the following statements can be made:

- The majority of lecturers adopt teacher-focused approaches as opposed to student-focused approaches;
- The majority of lecturers have the intention of teaching for information transmission as opposed to conceptual understanding;
- Their teaching contexts influence the majority of lecturers' conceptions of learning and teaching;
- Lecturers' conceptions of learning and teaching affect their approaches to teaching;
- The majority of lecturers have positive perceptions of PBL but see it as resource intensive and are unsustainable;
- The majority of lecturers do not feel their teaching contexts are appropriate to support the use of student-centered learning approaches;
- There is only a minority of lecturers with firm conceptions of teaching and learning as transmitting information and the accumulation of knowledge respectively;
- There is a minority of lecturers with firm conceptions of teaching and learning as facilitating learning and the development of conceptual understanding respectively;
- There is lack of an awareness of the roles assessment and workload play in determining student approaches to learning.

5. Discussion

Previous studies have suggested that the successful introduction of PBL requires lecturers, with student-centred concepts of learning and teaching, who adopt student-focused teaching approaches. Even though this study revealed that the majority of lecturers adopt teacher-focused approaches and have teacher-focused conceptions of teaching, it also showed that the lecturers' conceptions of teaching are influenced by their teaching contexts and their approaches to teaching vary accordingly. Furthermore, only a minority of lecturers hold steadfast teacher-focused conceptions of teaching and hence use teacher-focused approaches to teaching and these lecturers see PBL as inefficient and ineffective. In order to successfully adopt PBL, lecturers must show a willingness to fundamentally change their teaching practices and this research showed that teaching practices can be changed from teacher-focused to student-focused if the lecturers perceive their teaching contexts support these types of approaches. For instance if the class sizes are not too large, academic workloads are not too great and the lecturers have control over what and how they teach. In these conditions, lecturers who currently use teacher-centred approaches may move towards more student-centred approaches to support the development of conceptual understanding and problem-solving skills. The findings would seem to support Biggs (2003) when he stated that the reasons why PBL is not more widely used are not educational but organisational. However, even if these lecturers do begin to adopt student-centred approaches that does not inherently mean they will adopt PBL as a pedagogical approach. Marincovich's (2000) suggested that PBL goes against the 'grain' of lecturers who are mostly devoted to their discipline, eager to dispense knowledge and content-oriented and Perrenet et al. (2000) stated that in order for a pedagogical innovation to be successfully adopted it must reflect the nature of the profession. PBL does not necessarily reflect the way in which a physicist would work nor is it perceived as developing knowledge of theories or principles. However, if the model of PBL is changed to better reflect the type of learning that occurs during research it may be better accepted among physicists. Similar to a research project, PBL simply involves posing a problem before the students have learned the necessary knowledge. The problem tends to motivate the students and then know why they are learning, in the same way as the final year students do when working on their projects. If PBL is portrayed in this light and developed so that, as Miflin (2001) suggests, both types of lecturer, the student-centred and the more didactic type, have roles to play in the PBL curriculum its use may increase in physics education. However, as mentioned previously, if student-centred approaches such as PBL are to be accepted, the priority in curriculum and lesson design cannot be content ceverage as it is not possible to 'cover' the same amount of content with these approaches as it is with didactic appoaches. One model that may be more favourably adopted by physics lecturers, namely, project-based learning (Blumenfeld et al., 1991). This does share some similarities to PBL in that the students work in groups on projects and they can have the same roles and be assessed in the same way as in the PBL approach. However, in project-based learning the group project work runs parallel to a series of lecturers where the knowledge they need to successfully complete the project can be obtained. Therefore the pedagogical emphasis of project-based learning is to integrate and apply the knowledge gained through the lectures, while in PBL the emphasis is also on the acquisition of knowledge and understanding. So although the problem, or project, drives the acquisition of knowledge the students can get this from traditional lectures. This has been widely accepted in engineering education (Mills and Treagust, 2003; Perrenet et al., 2000), which has many similarities with applied physics. Perhaps, if PBL continues to be introduced and used in physics education, the model will continue to evolve to better suit the discipline and the epistemological beliefs of the lecturers.

References

Barrows, H. S. and Tamblyn, R. M. (1980), *Problem-based Learning, An approach to Medical Education,* New York, Springer.

Biggs, J. (2003), *Teaching for Quality Learning at University: What the Student Does*, 2nd edn., Maidenhead, SHRE/Open University Press.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991), Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, 26 (3 & 4), 369-398.

Booth, S. A. (1997), On Phenomenogrpahy, learning and teaching, *Higher Education Research and Development*, 16, 135-159.

Bowe, B. and Cowan, J. (2004), *A comparative evaluation of problem-based learning in Physics: A lecture-based course and a problem-based course*, in Challenging Research into Problem-based Learning, Savin-Baden, M. and Wilkie, K. (eds) SRHE / Open University Press

Ching, C. C. and De Gallow (2002), *Fear and loathing: Faculty reactions to developing problem-based learning for a large research university*, Proc. PBL 2002 - A Pathway to Better Learning, Baltimore, USA.

Dall'Alba, G. (1990), Foreshadowing Conceptions of Teaching, Research and Development in Higher Education, 13, 293-297.

Kandlbinder, P., Mauffette, Y. (2001), Perceptions of Teaching by Science Teachers using a Student-Centre Approach, *in The Power of Problem-based Learnin*g, Little, P. and Kandlbinder, P. (eds), Proc. of the 3rd Asia Pacific Conference on PBL, 9-12 December.

Kember, D. (1997), A reconceptualisation of the research into university academics' conceptions of teaching, *Learning and Instruction*, 7, 255-75.

Linder, C. J, and Marshall, D. (2003), *Teaching Focus in Higher Education Physics and Students' Conceptions of Good Teaching: a relational perspective*, Conf Proceedings European Science Education Research Association, Netherlands.

Marincovich, M. (2000), Problems and promises in problem-based learning, in O. S. Tan, P. Little, S. Y. Hee, and J. Conway, (eds), *Problem-based Learning: Educational Innovation Across Discipline*s, Singapore: Temasek Centre for Problem-based Learning.

Martin, E and Ramsden, P. (1993), An expanding awareness: how lecturers change their understanding of teaching, *Research and Development in Higher Education*, 15, 148-155

Marton, F. (1986), Phenomenography - a research approach to investigating different understandings of reality, *Journal of Thought*, 21, 28-49.

Marton, F. (1994), Phenomenography. In T. Husen & T. N. Postlethwaite (Eds*.), The international encyclopaedia of education* (2nd ed., Vol. 8, pp. 4424–4429). Oxford, U.K.: Pergamon

Marton, F. and Booth, S. (1997), *Learning and Awareness*, Maywah, New Jersey, Lawrence Erlbaum.

Miflin, B. (2001), Mediating a leap of faith: Lessons from the experience of preparing teachers for problem-based learning, in *The Power of Problem-based Learning*, Little, P. and Kandlbinder, P. (eds), Proc. of the £rd Asia Pacific Conference on PBL, 9-12 December.

Mills J. E., and Treagust, D. F. (2003), Engineering Education - Is Problem-based or Project-based learning the answer? *Australasian Online Journal of Engineering Education*, http://www.aaee.com.au/journal/online.htm

O'Grady, G., (2004), The Dangers of PBL (and other instructional fads): Beware the epistemological hole in the practice of PBL. Paper presented at the PBL 2004 Conference, Cancun, Mexico

Perrenet J. C., Bouhuijs P. A. J., Smitts J. G. M. M. (2000), The Suitability of Problem-Based Learning for Engineering Education: theory and practice, *Teaching in Higher Education*, 5 (3), 345-358.

Prosser, M., Trigwell, K., and Taylor, P. (1994), A phenomenographic study of academics' conceptions of science learning and teaching, *Learning and Instruction*, 4, 217-231.

Prosser, M., and Trigwell, K. (1999) *Understanding Learning and Teaching: The experience of higher education*. SRHE and Open University Press, Buckingham.

Ramsden, P. (1991), Context and Strategy: situational influences on learning, in *Learning Strategies and Learning Styles*, Schmeck, R. R. (ed.) 159-184, Plenium Press, New York.

Ramsden, P. (1991b), A performance indicator of teaching quality in higher education: the course experience questionnaire, *Studies in Higher Education*, 16(2), 129-150

Savin-Baden, M. (2003), Facilitating *Problem-based Learning- Illuminating Perspectives*, Open University Press/SRHE, Buckingham.

Trigwell, K. and Prosser, M. (1996), Congruence between intention and strategy in science teachers' approach to teaching, *Higher Education*, 32, 77-87.

Trigwell, K, Prosser, M. and Taylor, P. (1999), Relations between teachers' approaches to teaching and students' learning, *Higher Education*, 37, 57-70.
Trigwell, K. and Prosser, M. (2004), Development and use of the Approaches to Teaching Inventory, *Educational Psychology Review*, 16(4), 409-424.
Walsh, L.N., Howard, R.G. & Bowe, B. (2007), Phenomenographic study of students’ problem solving approaches in physics, Phys. Rev. S T Phys. Educ. Res. 1, 020108