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ABSTRACT

This self-study was designed to explore problem based learning (PBL) as an instructional approach in the context of a large preservice science education course. It addressed how the teacher educator would structure PBL to foster student engagement in learning, how she would enhance her own pedagogical content knowledge through the self-study, and how student feedback about PBL could be used to inform her own practice. Data came from field notes during and after class, student-generated documents, students' workshops and group products, student journals, student interviews, and student surveys. Overall, PBL was new to the students. Nearly all participating students liked the PBL experience. Those who disliked it did not like group work or were confused by the open-ended nature of the problem. Those who were ambivalent felt PBL was too time-consuming and believed the content could have been learned equally well individually. The main challenges the teacher faced were facilitation and problem design. She found that she designed PBL problems that were to large and felt it would have been better to start small. She considered student feedback essential to informing her practice. (Contains 32 references.) (SM)

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Preparing pre-service science teachers: Can problem-based learning help?

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Introduction

> *In retrospect, I should have started with one small problem before introducing several in my course. When I collaborate with teachers, I always tell them to start small when they trying something new. I did not heed my own advice.*

These were comments I wrote in my journal in the latter part of this self-study in which I used Problem-Based Learning (PBL) as an instructional approach in an undergraduate science education methods course. Considering this was my first time using PBL, I felt that I had been too ambitious, devoting approximately two-thirds of my course to PBL. My goal in using PBL was to improve my understanding of it as an instructional approach, to explore how it could be used to enhance my own professional practice and the development of my pedagogical content knowledge (Grossman, 1990; Shulman,1986,1987), and to determine if it is a feasible approach for preparing pre-service teachers for the complexities of science classrooms. The first two goals are the primary focus of this paper.

Although there has been a significant shift in the last 15 years from a focus on teacher behaviours and skills as determinants of effective teaching to a focus on teacher cognitive processes (beliefs, values, and thinking) and how they inform teacher planning and decision-making, little emphasis has been placed on how faculty in higher education develop their professional knowledge for teaching. For example, Stark (2000) found that faculty members' disciplinary beliefs about knowledge had the strongest influence on their planning for courses and lessons. This line of inquiry, exploring how faculty members develop their knowledge base for teaching, provides a useful heuristic for exploring how the study of one's own practice can be used to improve teacher education courses and teacher education programs.

My choice of PBL for inclusion in one of my courses reflects a belief system that aligns with constructivism, an eclectic perspective on learning that focuses on both the individual and social construction of knowledge (Piaget, 1977; van Glasersfeld, 1995). Educators who hold a constructivist perspective structure learning experiences that help students construct their understanding of phenomena based on prior knowledge, learning styles, and developing perceptions. Students need to have opportunities to explore and reflect upon their ideas and how they fit with new ideas, and to question and share their thinking in a social context.

PBL provides a constructivist referent for teacher preparation. Furthermore, these beliefs align with how many other educators have attempted to reform teacher education (see Franks, 1994; Fried, 2000; Onslow & Laine, 2000; Sage, 2000). Graduates of teacher education programs need to have the necessary skills, attitudes, and dispositions to deal with the complexities of the present-day classroom. The increasing diversity of student groups, the movement towards the creation of inclusive classrooms, and the ongoing emergence of new technologies are factors that present a myriad of challenges to beginning teachers (Dean, 1998). Without developing the skills to become life-long learners and an inquiry-based approach to teaching, beginning teachers will be ill-prepared to deal with the realities of the classroom.

Reform in teacher education implies a willingness by faculty to embrace innovative approaches to teaching and learning and to engage in group and individual research and reflection about how to best improve their teaching. As a faulty member primarily responsible for the preparation of middle and high school science teachers, I designed this study to explore a student-centered learning approach referred to as PBL.

The Nature PBL

The origin of PBL can be traced to the work of Dewey (1944) who emphasized the connections amongst doing, thinking, and learning. Learning, according to Dewey, "should give students something to do . . .and the doing is of such a nature as to demand thinking or intentional connections" (1944, p. 154). PBL not only provides a tool for fostering thinking and active learning, it is also an instructional approach that has the potential to support many of the tenets of constructivist learning theories–learners actively construct knowledge through interactions with the environment and social negotiation (Savery & Duffy, 1995).

As an explicit approach to learning, the original model for PBL was developed at McMaster University's medical school by Howard Barrows. In adopting this approach, Barrows hoped to develop medical students' content knowledge and their ability to use that knowledge to address health care problems and "to provide appropriate care for future problems [students] . . .

must face" (Barrows, 1985, p.3). In the medical model, learning is student-centered and occurs in small groups, teachers act as facilitators or guides, problems are the organizing theme for learning, problems are the means for the development of clinical problem-solving skills, and new understanding occurs through self-directed learning (Barrows, 1996). In the modified PBL adopted in this study, most of these characteristics were present–learning occurred in small groups of three to four, I acted as a facilitator, learning was student-centered, and there was an emphasis on the development of content knowledge and problem-solving skills. However, each group of PBL students did not have a tutor as in the original model. Rather, each group tackled a different problem, working independently for most of the time. I was the facilitator for all groups.

Since the inception of the original PBL model, other variations have arisen in contexts outside the medical school. Although recent meta-analyses have focussed primarily on the outcomes of PBL instruction (Albanese & Mitchell, 1993; Vernon & Blake, 1993), little research has explored issues of process. Hence, this study focusses on issues of process in planning for and using PBL as an instructional approach. Without an understanding of how modified PBL formats are implemented and the conditions under which they may be effective, little can be garnered about the merit of PBL in pre-service teacher education.

Pedagogical Content Knowledge

All teachers possess a wealth of knowledge that informs their classroom practice. In recent years, this knowledge has been referred to as practical knowledge (Carter, 1990) or craft knowledge (Grimmett & MacKinnon, 1992). Van Driel,Verloop & De Vos (1998) refer to craft knowledge as knowledge and beliefs that guide "teachers' actions in practice" and are held in relation to curriculum, subject matter, students, and pedagogy (p. 674).

This paper focuses on the development of one form of craft knowledge–pedagogical content knowledge or PCK. The notion of PCK was first conceptualized by Shulman (1986, 1987) and has become a widely used concept in education as a vehicle to understand how teachers organize and conceptualize their teaching. Shulman refers to PCK as "the most powerful analogies, illustrations, examples, explanations, and demonstrations–in a word the ways of representing and formulating the subject matter that makes it comprehensible for others" (1986, p. 9). According to Shulman, PCK involves how the subject matter of a particular discipline is transformed for communication with learners. It includes a recognition of what makes specific topics difficult to learn as well as the conceptions students bring to the learning of those concepts. . Since its introduction, PCK has been interpreted in a variety of ways by educators. For example, Loughran et al. (1999) view the PCK of science teachers as a mixture of interacting elements (views of learning, views of teaching, understanding of content, understanding of students, knowledge and practice of children's conceptions, time, context, views of scientific knowledge, pedagogical practice, decision-making, reflection, and explicit versus tacit knowledge of practice/beliefs/ideas), that combine to give insight into PCK. Likewise, Magnusson et al. (1999, p. 95) describe PCK as "the transformation of several types of knowledge for teaching" including subject matter knowledge, pedagogical knowledge (classroom management, educational aims) and knowledge about context (students, school). Grossman (1990) views PCK as being composed of four district components: knowledge and beliefs for teaching subject matter; knowledge of students' understanding, conceptions, and misconceptions of particular topics in a discipline; knowledge of curriculum; and knowledge of instructional strategies and representations. Hutchings and Shulman (1999) have extended the notion of pedagogical content knowledge into a Scholarship of Teaching, emphasizing the need for faculty understanding and knowledge, acquired through inquiry into teaching, to be shared in a public format for review and scrutiny.

In articulating how my knowledge base for teaching changed as a result of this self-study, I use the Grossman framework to communicate my findings. I also acknowledge that although the elements of PCK may be discrete in theory, in reality they intertwine in complex ways to transform PCK.

Although many studies have been completed within the context of teaching and learning in a range of disciplines to explore teachers' PCK (K-12), this literature will not be reviewed here. However, van Driel and De Yong (2001) did review studies of PCK and concluded that there are four primary sources for the development of PCK: disciplinary education, observation of classes, classroom teaching experiences, and specific courses and workshops. The development of my PCK was informed by personal reflection on my beliefs and practices as a teacher educator and observation and interaction with my students during PBL implementation

Research Questions

This self-study was designed to explore PBL as an instructional approach in the context of a large pre-service science education course. In planning for and implementing PBL, I hoped to enhance my own PCK and to immerse students in authentic learning experiences that would encourage them to adopt an inquiry-based approach to teaching. More specifically, this paper addresses the following research questions: (a) How will I structure PBL to foster student engagement in learning?, (b) How will I enhance my own pedagogical content knowledge through this self-study?, and (c) How can student feedback about PBL be used to inform my own practice?

The Class and Course

The first iteration of this study was conducted in the Winter semester of 2002. Thirty-three pre-service students were enrolled in an advanced three-credit hour undergraduate education methods course, *Advanced Studies in Science Education*, a mandatory component of a sixty-credit hour program that results in certification to teach middle school or high school science in Canadian schools. Most of the students were in a consecutive program, having entered the program after completing a Bachelor of Science, while five were in a concurrent program, completing a Bachelor of Science and Bachelor of Education simultaneously. Students ranged in age from 21 to 40 years, while the class was balanced in terms of gender. Upon program commencement, most had limited teaching experience in K-12 settings. At the end of this course, students were expected to: a) demonstrate, by participation in classroom seminars and activities, an in-depth knowledge and understanding of the discipline of science, b) analyze possible problem situations and challenges that may arise in the context of science teaching, c) implement instructional and assessment strategies to foster scientific literacy, d) describe strategies for implementing an STS (science-technology-society) emphasis in a science classroom, e) identify the safety precautions teachers should consider at the beginning of the school year, f) explain the role of the teacher in developing and implementing science curriculum, g) reflect on their developing beliefs about the nature of science, and h) examine the role of practical work in learning science. The course builds on ideas and concepts introduced in an introductory course completed by students in the Fall semester of the program.

The group met for twelve weeks on Tuesdays and Thursdays for 80 minutes each day. On Tuesdays for the first seven weeks, I engaged students in a range of learning activities such as lectures, case studies, web-based learning activities, whole-group and small-group discussions and investigations, and seminars designed to emphasize learning outcomes, pedagogy, methodology, and content. During the Thursday sessions in the first seven weeks, students worked in collaborative PBL groups of four or five to address a pedagogical problem focussed on some aspect of science teaching and learning. The Appendix provides examples of some of the problems used in the course. Groups were assigned different problems, after being asked to rank their top three issues from the following list: integrating curriculum, scientific inquiry, cooperative learning, equity and science, curriculum differentiation, portfolio assessment, multiple intelligences theory, and learning styles.

In the last five weeks of the course, each PBL group was responsible for delivering an 80-minute workshop based on a solution to the assigned pedagogical problem. The planning and delivery of the workshop was given a grade. In addition, each group was required to create a product that illustrated their understanding of the issues raised in the problem. In terms of individual assessment, each student completed a PBL journal that was a record of his or her thinking about the PBL process and a peer-evaluation of how individuals contributed to the overall effectiveness of the group. Approximately two-thirds of the course was devoted to PBL.

Methodology

Of the 33 students who enrolled in the course, 28 decided to participate in the study. When research is conducted with one's own students, issues of power become paramount. I adopted principles premised on openness and fairness; I assured students that their participation or nonparticipation in the study would not affect their academic performance. Data, over and above normal course requirements, were collected after the submission of final grades.

In studying my own practice, I adopted classroom-based action research (Kemmis & McTaggart, 2000) as a strategy to explore PBL. I engaged in self-reflective spirals of "planning, acting, observing and reflecting, with each of these activities being systematically and self-critically implemented and interrelated" (Grundy, 1982, p. 23).

To enhance the trustworthiness of the study (Guba, 1981), I adopted many of Wolcott's principles (Wolcott, 1990) such as listening extensively, recording observations accurately, writing early, reporting fully, being candid, using primary data when reporting, obtaining feedback from others, and writing accurately. Furthermore, to view the research from many perspectives, I used a variety of data collection methods and sources. Field notes were recorded, during and after classes, describing classroom events and my interpretation of those events. Student-generated documents, a personal technology that requires contextualized interpretation (Hodder, 2000), served as another source of data. Students' workshop plans, group products, and individual journals were analyzed to enhance data analysis and interpretation. Informal conversational interviews (Patton, 1990) occurred with students during and after scheduled class sessions, while semi-structured interviews were conducted with seven student volunteers at the end of the course. In addition, at the end of the course I asked a colleague, an experienced user of PBL, to interview me about my experiences in using PBL as an instructional approach. This interview fostered self-reflection, became a learning opportunity as we shared our ideas about PBL, and served as a source of data.

All interviews were audiotaped and later transcribed; careful notes were taken after each interview. An open-ended written questionnaire, administered at the end of the course, asked students to respond to probing questions about their perceptions of many aspects of PBL and what they learned through participation in the PBL experience. These surveys, completed when I was not in the class, were stored in the Dean's office until after my course grades had been submitted.

Throughout the study, data analysis coincided with data collection. According to Marshall and Rossman (1999), "data analysis is the process of bringing order, structure, and interpretation to the mass of data collected" (p. 150). In analyzing the data, I used grounded theory (Strauss & Corbin, 1998), beginning with open coding to identify concepts. I assigned labels to units of text from transcripts, field notes, journal entries, and interviews, forming the basis for identifying concepts throughout the data set. Simultaneously, I engaged in constant comparison, identifying similar incidents and events for grouping into the same conceptual categories. I then used axial coding, generating main categories and subcategories, to establish larger categories and make connections among larger categories and subcategories.

Results/Discussion

As a teacher educator preparing students to become middle school and high school science teachers, it is extremely important that I have strong subject matter knowledge in science. Equally important is having strong PCK so I am able to effectively model for students how to integrate science subject matter knowledge and pedagogy and how to engage students in learning that makes the content of methods courses comprehensible and relevant. In other words, one of my goals is to assist my students in developing their PCK so they will be better prepared to deal with the complexities of the science classroom. To achieve this goal, novice teachers must participate in a range of learning experiences in both university classrooms and K-12 classrooms. Thus, I adopted PBL as one instructional approach to help reach this goal.

Before examining how my PCK was transformed, I will share with the reader student perceptions of the PBL experience. The changes in my PCK occurred in the context of classroom practice and were informed, to a large extent, by both informal and formal feedback from students.

Student perceptions of PBL. For the 28 students who chose to participate in this study, this was the first time they had been exposed to PBL. Their insights about the nature of the problem, facilitation, assessment, and satisfaction about learning through PBL informed my thinking and classroom practice

The Nature of the Problem- The seven problems completed during the course focused on science in relation to gender equity, interdisciplinary curriculum, cooperative learning, differentiation and gifted learners, portfolio assessment, multiple intelligences and learning styles, and evolution. Students' journal reflections and responses to survey questions revealed that most found the problems relevant to science teaching and learning:

> *This problem really opened my eyes and made me aware of many issues* (Student A)
> *This was a problem any teacher might encounter in his/her science classroom* (Student D)
> *I hope to use these very important theories [MI theory and Learning styles] in my classroom* (Student L)
> *I think it is very important to tackle this problem [how to teach evolution in a classroom]; teachers have to be careful not to impose their values and beliefs on students* (Student P)

However, one student reported that his topic was irrelevant to science teaching: "Although this is a valuable topic, I do not see the connection to science teaching." Two other students did not explicitly connect the problem to science teaching: "This is more geared towards a teaching strategy" and "the problem needs to be more exclusive to science."

Although most students considered the problems relevant, students who tackled gender equity and portfolio assessment reported that their problems were not overly complex. In another instance, a student felt his problem was far too complex and involved too many subproblems: "This problem was very difficult and involved too many issues."

Facilitation- Throughout the implementation process, as I facilitated, some groups struggled with their problem for longer periods of time than others. All problems were multi-faceted; however, some were extremely open-ended and introduced a range of subproblems within the larger problem. With the more complex problems, groups spent more time and energy defining the problem, exploring the issues raised by the problem, and locating resources. For example, about 42% of the groups reported that they had too much time to complete the problem; several students felt they could have addressed two problems in the time frame I provided. In contrast, 50% of the students indicated they had adequate time to address the problem.

When asked if they received enough support from the professor during the PBL process, 15 of the 28 students responded in the affirmative, stating that they felt the level of support was adequate. Those who desired more support varied in their reasons for wanting more support. Six students felt there was confusion at the beginning of the PBL process when the problem was introduced. Two students wanted more direction about expectations for the assessment (workshop and group product), while three students wanted a little more time to meet with me throughout the process. Two students wanted more guidance about the direction to take for solving the problem. One of the two stated that he "would have liked to have been told if the group was headed in the right direction," while the other student said she "always felt the group was not headed in the right direction."

Based on my observations of the groups and feedback during class meetings, I felt most groups functioned fairly equitably. There was sharing of ideas, role differentiation within each group, and equity in terms of workload. It was surprised, at the end of the process when I was reading the journals to discover that one group had not functioned well. "Although I like PBL, my group fell apart at the end. This became the least enjoyable group experience ever" (Journal comments, pre-service student). Although the final product created by this group was high in quality and presented a very feasible solution to the problem, the group struggled tremendously with reaching a consensus on the content and format of the final product.

Performance-Based Assessment and PBL-The assessment of the PBL included an individual journal, peer assessment, the creation of a group product of choice, and the delivery of an 80-minute workshop. I was especially interested in students' perceptions of the workshops as they required a considerable amount of course time; thus, for both presenters and participants, I wanted to ascertain the efficacy of these workshops.

Although I judged all workshops to be well-developed in terms of content and the exploration of issues (grades ranged from a B+ to an A+), four of the seven presentations lacked significant variety in terms of workshop learning activities; there was a heavy reliance on lecture and *PowerPoint* presentations. Furthermore, students did not build enough time into the process for debriefing and feedback.

In responding to a question about the merit of the workshops, 26 the 28 students reported that they were learning about many aspects of science teaching and learning during the workshops. However, the amount of learning depended on the quality of the workshop and the nature of the activities used. The two students who felt they were not learning from the workshops thought the presentations were boring: "Once your workshop is done you are not interested" and "I do an activity but it is not debriefed."

Student Satisfaction with PBL-Most students were satisfied or very satisfied with learning through PBL. Twenty-one students gave it a strong endorsement, while four disliked the experience. Three students were ambivalent about the entire experience. Reasons for enjoying the PBL experience included the opportunity to collaborate with classmates, the motivation that resulted from having control over one's own learning, and the potential of PBL to make the science teaching more comprehensible. These reasons are reflected in journal entries: "The PBL experience was new so I was motivated to try it. I enjoyed working in groups and the opportunity to collaborate with others," "I had control over my learning, therefore I had more interest in learning, " "The freedom was a definite motivation; it is your work," "The group helps to motivate you to get things done," and "PBL makes learning more personal and you find out an incredible amount about a topic."

The four students who disliked the PBL experience did not like group work or were confused by the open-ended nature of the problem. Those in the "ambivalent" group felt PBL was too time-consuming and believed the content could have been learned equally well individually. Some of their comments were: "I can see the potential of PBL, but it is so time-consuming," "I found it difficult to adjust to; I had never used it before," "It was not more or less appealing than any group work," and "I have mixed feelings about PBL; I enjoy groups but our group was not motivated."

Pedagogical content knowledge and transforming practice. Many elements of my PCK were transformed as I planned for and implemented PBL. Although I will use the Grossman framework to examine specific components of my PCK, in reality they are interrelated and interact in practice.

Conceptions of purposes for teaching subject matter- My rationale for choosing PBL as an instructional strategy is consistent with my beliefs about how students learn. They need opportunities to construct their own understanding of concepts both individually and in group contexts. PBL allowed my students to work collaboratively to generate understanding about science teaching and learning, yet provided a forum for individual reflection and meaning-making. Most students found the problems to be relevant to science teaching and learning, an important feature of PBL if it is to promote the development of insight and skills for science teaching.

Despite the complexity of PBL as an instructional strategy, my belief in the necessity for structuring teacher education courses that embed theory in the context of the real classroom has been reinforced and validated Although it is not always possible to link field-based assignments in the context of university methods courses, I believe PBL provides a feasible alternative for examining real-world, authentic classroom teaching challenges.

Knowledge of students' understanding -The insights I garnered through reading and analyzing student journal reflections were extremely informative. One area of concern that arose was students' inability to use the problem as a basis to integrate the content of science with pedagogy. In other words, some students were unable develop insight into how to transform science content using a range of instructional approaches. This may be a consequence of having limited K-12 classroom experience or a function of the problems I designed. I need to give more attention to ensuring that students complete products that require them to show how content and pedagogy are interwoven. The design of lesson plans is one means to achieve this goal.

All students did not like learning through PBL. The course had a very heavy weighting on PBL, and consequently, perhaps did not cater enough to a range of learning styles. PBL should be one of many instructional strategies that are used within a course.

Curricular knowledge- In this modified PBL format, I chose the topics for inclusion in the course. This is necessary since students may be unaware of topics that have relevance for science teaching. Conversely, the incorporation of problems, based on student choice, can foster higher levels of motivation and interest in learning. Professors should ascertain students' prior knowledge about particular topics before selecting the topics for inclusion in a course. For example, one student suggested that the students be given the opportunity to design their own problem.

In terms of problem complexity, I discovered that many problems varied in terms of complexity and the energy needed by each group to define the problem. Problem design is a huge challenge when designing PBL curriculum. In the modified PBL format adopted in this study, to provide consistency and fairness, it would have been preferable to make the problems more equitable in terms of intellectual demands placed on the students.

Knowledge of instructional strategies-Although this study explored the development of my PCK through the implementation of one instructional approach, I developed a greater understanding of many different aspects of instructional practice, such as assessment, collaborative group work, and facilitation. PBL is a complex instructional approach that requires the use of many skills by a teacher. One area that needed considerable improvement was my facilitation. Although I believe my feedback was helpful to groups, many wanted more frequent feedback and more clarification at the outset about the nature of PBL and what to expect. A small number of students seemed uncomfortable with the open-ended nature of the problem and may have confused the ideas of support and guidance. I wanted to provide optimal support to groups, while not being too directive in terms of finding solutions to the problems.

Changes in practice. Since the completion of this study, I have continued to use PBL, making several adjustments and modifications based on what I learned during the first cycle of implementation. I continue to use it in ED 4511, the course described in this study, and have also incorporated a small PBL component into an introductory science methods course for elementary pre-service students. Some of my adjustments in the second implementation of PBL include:

1. PBL format: Although using several pedagogical problems in a course allows students to explore topics in considerable depth, my initial format was far too ambitious. Instead, I chose to implement two smaller problems, with less time overall devoted to PBL in the course. In addition, I came to the realization that the use of PBL does not preclude the use of other instructional strategies. Hence, during the implementation of the current

problems, I provided some starting resources, utilized videos to help groups explore issues, and engaged groups in more whole-group discussions. This can offer more direction for those who are threatened by the open-ended nature of PBL.

2. Student input: At the beginning of the course, I asked students (a group of 40) to identify their three biggest concerns at this stage in their teaching careers. Classroom management was cited as a top concern by 90 percent of students. Equally problematic for students was their perceived lack of knowledge about how to meet the needs of divers learners in a science classroom. Based on this feedback, I designed one problem on the struggles of a beginning science teacher with classroom management and a second problem on how to differentiate curriculum in a mixed-ability science classroom.

3. Assessment: This is always a challenge when using any instructional approach that is student-centered. I have continued to require that students create a product to demonstrate learning. In one problem, I specified the product–an annotated bibliography and a CD-ROM or brochure. The second PBL incorporated a product of choice that had to show evidence of how to integrate science content, pedagogy, and differentiation strategies. Many students chose to develop lesson plans, while one group designed a newsletter. Although I did not use a workshop format, I did allow time for groups to share their ideas and products in small group settings at the end of each PBL experience. Furthermore, if there were gaps in some aspects of students' learning, I addressed this with the whole group after assessment was complete.

4. Feedback: I am currently providing students with more frequent feedback re the PBL content and the process. Students complete logs at the end of each meeting and I check them more frequently as a means to monitor group functioning and unfolding understanding of the problem. I hope, in the future, to respond to journal entries more frequently, and to introduce a small problem before tackling one that will be graded. The

exposure to a small problem may help students develop a higher comfort level with PBL.

5. Group functioning: This has become a more focused aspect of the self-study in the current iteration. It seems to be a greater concern than it was in the previous use of PBL. Several groups have struggled with group dynamics. I am exploring the idea of engaging groups in some initial community-building activities before starting a PBL. Group members may be strangers, and providing an explicit forum for "getting-to-know each other" may promote group rapport and trust.

Implications

Although there are several implications that readers may garner from this study, I will focus on two major themes: the nature of PBL instruction and the importance of self-study in teacher education. In my first attempt at designing and implementing PBL curriculum, I was overambitious, designing large PBL problems and devoting a large percentage of my course to PBL learning. It would have preferable to take a more modest approach for a variety of reasons. Because PBL is a very complex instructional approach and is challenging to implement, especially with large classes and one facilitator, it would be more manageable for any teacher to start small. Not only would this increase the comfort level of the teacher, it would also alleviate student tension. Several of my students had never used PBL as an approach to learning, and a few were unaccustomed to learning through constructivist approaches. Starting with a small problem or PBL posthole, providing students with a strong rationale for adopting a new instructional approach, and teaching them explicitly about PBL before introducing a problem, would allow students to ease into a new learning situation.

My two biggest challenges in using PBL have centered around facilitation and problem design. I am striving to find better ways to provide PBL groups with more frequent feedback that will guide their work. As well, although my problems were relevant to science teaching, designers and facilitators of PBL must constantly find ways to make problems engaging and meaningful. For example, problems can vary on a number of elements: the degree of structure in a problem, the problem situation (real to simulated), the number of resources provided by the instructor, the concepts and skills students are expected to address, and the level of complexity within a problem (Sage, 2000). Because teaching is so contextual, these elements of PBL will need to be adjusted accordingly.

The adoption and fine-tuning of PBL or any new instructional approach will only occur if faculty and other teachers are willing to engage in critical, systematic reflection through self-study. My reasons for engaging in self-study are twofold: it provides a professional challenge and the potential for generating more satisfaction if I believe I am being more effective as a teacher and pre-service students will benefit if they are better prepared for the realities of classroom teaching. One of my goals has been to foster, in students, an inquiry-based approach to teaching by modeling constructivst approaches in my own teaching. To achieve this goal, I used PCK as a heuristic to analyze, reflect upon, and make changes to my own practice. By capitalizing on my students' insights and beliefs about PBL, I was able to enhance many aspects of my PCK that now can then be transferred to other areas of my teaching, with other topics and other groups of students.

From a broader perspective, the importance of self-study cannot be undervalued. Strengthening teacher education necessitates a concerted effort by faculty to work collaboratively to improve the quality of teaching. Although I did seek input from colleagues who were experienced in using PBL (the project was taken on as an individual initiative), I believe it would have been far more beneficial to have conducted this study with collaborators.

Final Comments

I continue to believe that PBL and other active learning strategies should be used in teacher preparation programs. Eliciting ongoing feedback from students is essential if PBL is to be refined and adapted for varying groups of students. Likewise, ideally it would be best to work collaboratively with colleagues to share, discuss, and analyze this feedback. Furthermore, the use of PCK provides a useful framework to make the knowledge base of higher education teaching explicit. I encourage all faculty to engage in self-study for the purpose of personal and professional improvement and for promoting a scholarship of teaching. Can problem-based learning help? Yes!

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Appendix

Sample Problem A:

<u>So, What's So Bad about Competition?</u>

Janice Langdon is a first-year Biology teacher. She would describe her approach to teaching science as highly student-centered and premised on a belief that students learn best when they are actively engaged in their learning. It is early in the year and she has been doing some group work in her classes. To her dismay, she discovers that several problems are arising whenever she attempts to structure collaborative learning experiences. There seems to be incessant arguing, groups are not on-task, and productivity levels are low. She had assumed, after 11-12 years of schooling that her students would be adept at working within teams. In one Level-three Biology class, she decides to use part of the class to explore her concerns and to get feedback from students.

Some of her students share their ideas readily when asked about why they seem to be struggling when they have to work in teams:

> *I am sorry miss. I know you say team work is important, but it takes too much energy and thinking. Just give me the notes and talk and I will learn just as well. (Jim)*
>
> *Miss L. We talked about learning styles in social studies class. I work best on my own. No offence to you guys . . you slow me down. (James)*
>
> *How about our grades? Why should I work like a dog when everyone will not? Why should we all get the same grade? (Sarah)*
>
> *Miss, other teachers do not require us to work in groups. This really sucks! (Joe)*
>
> *I like groups sometimes, Miss Langdon. I would like them better if we could get along and work as a team. (Isha)*

Janice wants to continue with her goal of fostering collaborative team work. However, there are several concerns she needs to address. How can Janice address these concerns? What changes in her classroom practice will be needed?

Sample Problem B:

Equity in the Science Classroom

Context: High School Science Classes-Grade 10

After attending a workshop session on equity in science education at the New Brunswick Teachers' Association provincial high school conference in Moncton, you have become more cognizant of your classroom behaviours.

After monitoring your behaviour for about two weeks, you discover that students are getting different amounts and types of attention from you, based on their gender. In general, boys are getting more positive and negative attention from you than are girls.

What, if anything, can you do to change this imbalance?

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