Journal of Research and Reflections in Education
June 2008, Vol. 2, No.1, pp 66 -91
http://www.ue.edu.pk/jrre

Using PBL to Enhance Student Teachers' Science Content Knowledge

Martin Thomas

Abstract: Being a teacher educator, I came across many problems throughout my teaching experience at St. Margaret's Institute of Education Karachi (pseudo name). Some of these problems were simple and I was able to solve those by using my prior knowledge and experience. However, some of the problems were complex and I was unable to solve these satisfactorily even by using my prior knowledge and past experience. Complex problems were usually dense and interconnected therefore they developed patterns of regularity and consistency and hence became quite obvious and noticeable. The patterns formulated by the problems encouraged me to reflect upon them and identify the causes of problems. I started keeping a reflective journal to record distinctive, unexpected as well as pattern forming events of my Science curriculum studies' classes. I also recorded my reflections on each of the recorded events and problems and made inferences from each of them. I also started consulting research journals and other library and Internet resources as well as my research supervisor and critical friend. With this activity I was able to find some of the root causes of different problems. I isolated one problem which was intense and affecting a large number of Science students.Most of the students were weak in Science content knowledge and therefore were unable to show good performance in most of the class activities, namely, Science tests, worksheets, presentations and assignments. They also found difficulty when they went to the schools for teaching practicum as they could not explain topics well and showed an inability to handle students' questions. Some of them even gave wrong information in answering students' questions which led to lack of confidence among student teachers and they could not manage students' behaviour very well. These interconnected problems encouraged me to help student teachers of St. Margaret's Institute of Education enhance their Science content knowledge. While working with student teachers, I had to keep in mind that educational institutes for teachers place more emphasis on pedagogical content knowledge rather than on the subject content. It is expected that a focus on subject content would have occurred prior to their taking Science Curriculum Studies Unit. Therefore, the anticipation of the teacher educator is that any focus on content within the unit would be largely in relation to pedagogical approaches to the transfer of content knowledge. For this reason, I decided to use the Problem-Based Learning technique

(Barrows, 1984; Boud, 1985; Boud & Feletti, 1991; Duch, 1995; Woods, 1985) to enhance student teachers' Science content knowledge. The problem mentioned above could not be solved in one or a few classes. Therefore, I used the Action Research method (Burns, 1997; Henry & Kemmis, 1985) to enhance student teachers' Science content knowledge. There seemed to have successes in terms of enhancing student teachers' Science content knowledge. This research had three cycles and was completed in five months.

Keywords: Science curriculum, science content knowledge, pedagogical content knowledge, problem based learning techniques

Introduction

Being a teacher educator, I came across many problems throughout my teaching experience at St. Margaret's Institute of Education Karachi (pseudo name). Some of these problems were simple and I was able to solve them by using my prior knowledge and experience. Problems that occurred because of time constraints, shortage of certain material supplies and unexpected holidays and so on were some of these problems. However, some of the problems were complex and I was unable to solve them satisfactorily even by using my prior knowledge and past experience.

Complex problems were usually dense and interconnected. For example a student teacher missed her Science classes whenever she was due to give a presentation. Another student teacher exhibited uncomfortable behaviour whenever she was asked to work in a group. Some students showed poor performance in particular portion of most of the worksheets. The problems amongst the Science students developed patterns of regularity and consistency and hence became quite obvious and noticeable. The patterns formulated by the problems encouraged me to reflect upon them and identify the causes of problems.

I started keeping a reflective journal to record distinctive, unexpected as well as pattern forming events of my Science Curriculum Studies' classes. I also recorded my reflections on each of the recorded events and problems and made inferences from each of them. These critical reflections indicated that some of the events and problems were interconnected. They dominated the routine activities of my Science classes. Even though some of the problems were very prominent, they varied in terms of their level of intensity and effects.

A teacher should cater to individual differences in the class (Woolfolk, 1998). However, while helping students to solve their problems s/he should start with those problems which are intense and affect most of the students in class. Such complex problems can distort the performance of most of the students in the class and consequently can result in failure of the lesson taught. Therefore to help my Science students solve their problems, I isolated an issue which was the most prominent and was affecting most of them.

Through my observation and reflections I found that the majority of the students were weak in Science content knowledge and therefore were unable to show good performance in many of the class activities, namely, Science tests, worksheets, presentations and assignments. They also found difficulty when they went to the schools for the teaching practicum as they could not explain topics well and showed an inability to handle students' questions. Some gave wrong information in answering students' questions which led to lack of confidence among student teachers and an inability to manage students' behaviour. These interconnected problems encouraged me to help student teachers of St. Margaret's Institute of Education enhance their Science content knowledge. I planned to conduct a research with the student teachers of the institute in order to overcome the problem. With the help of literature review, I chose action research as a research method and Problem Based Learning (PBL) as a teaching technique to help student teachers enhance their Science content knowledge.

Background of St. Margaret's Institute of Education

St. Margaret's Institute of Education was inaugurated on October 1, 1991 under the auspices of the Catholic Bishops' Conference of Pakistan. The Institute is situated in Saddar which is the heart of the city Karachi, Pakistan. Since its beginning, the Institute is operating under the guidance of Australian sisters (nuns) who have been joined by other Australian volunteers. An increasing number of St. Margaret's graduates are now employed on the institute staff. The institute has sufficient amount of resources such as spacious rooms, assembly room, conference room, a computer room and a mini Science laboratory. It also has a resource room which is equipped with a number of resources such as projectors, tape recorders, charts, posters, real objects, models, slides and so on. It also has a huge library which contains more than 40,000 books.

St. Margaret's Institute conducts a one year full-time Bachelor of Education (affiliated with Karachi University) and a one year full-time International Graduate Certificate of Education (licensed by Australian Catholic University). Most of the St. Margaret's students are enrolled for both Bachelor of Education (B.Ed) and International Graduate Certification of Education (IGCE) but some of them just for IGCE. However, both B.Ed/IGCE students attend classes together.

Apart from B.Ed/IGCE courses, the Institute also conducts a two year Master of Education (preliminary) course required for entrance to the Master of Education (M.Ed) and a 15 months Master of Education (affiliated with Karachi University and licensed by Australian Catholic University).

Aim of the research study

The aim of the research study was to use Problem Based Learning (PBL) in order to help B.Ed/IGCE students to enhance their Science content knowledge.

The following paragraphs highlight the research methodology, process followed for conducting the research study and results of the research study.

Methodology

Different authors (such as Burns, 1997; Bouma, 1996; and Gay, 1992) have defined research as a systematic investigation process which is developed to collect information about a subject or to find the answer to a question. It is an unending search for truth that helps to correct errors and misconceptions about a subject. According to Gay (1992), various research studies can be classified either on the basis of purpose for which they are conducted or on the basis of the method used to conduct the research. One of these research methods is action research. The primary concern of action research is to solve local problems in a local setting (Gay, 1992) such as a particular classroom in a particular context while not obtaining scientific knowledge that can be generalized (Burns, 1997).

As I was trying to solve problems of a particular context, I decided to use action research method of study. I took guidance from the works of Burns (1997) and Henry and Kemmis (1985). According to Burns and Henry and Kemmis, action research is a spiral-like process. Each of the cycles of the spiral includes four steps including: plan, act, observe and reflect.

Prior to the first cycle of action research, the researcher brainstorms some initial ideas about the problems on the basis of his/her observation of the situation in which the research is to be conducted. This initial idea leads to finding facts from the given situation. From the facts and literature review, the researcher then forms a general plan to improve the situation by overcoming the problem (Burns, 1997).

In order to conduct my action research, I followed similar procedure as suggested by Burns (1997) and Henry and Kemmis (1985). A detail of the procedure followed is given below:

Stage 1: Reconnaissance

Apart from data gathered through reflective journal, informal discussions with students, with my critical friend and with my mentor, I also found information about the process of student teachers' selection for B.Ed/IGCE courses at St. Margaret's Institute of Education. In this regard I came across the following information:

- Student teachers undergo the following process before selecting a subject as their teaching unit.
  1. Those student teachers who have sufficient background knowledge of the subject can opt for General Science Curriculum Unit.
  2. They have a face-to-face interview with the Science Curriculum Unit lecturer to discuss the opportunities and difficulties in selecting General Science Curriculum Unit.
  3. During their initial classes student teachers sit for a diagnostic test which helps them to determine their strength and weakness and decide whether or not they should opt for General Science Curriculum Studies.

- Those students who have completed their Bachelor of Science (B. Sc) in specialized subjects such as Biology, Chemistry and Physics, usually opt for specialized curriculum studies unit in those areas. Due to this trend among students, only those who have either taught General Science in primary or secondary classes for sometime, or are interested in teaching General Science in future, choose the General Science Curriculum subject. During the year of my action research, all those student teachers whose minimum qualification was at least Bachelor of Science chose Biology Curriculum Studies or Chemistry Curriculum Studies; none of them chose General Science Curriculum Studies.
- Some student teachers feel considerable difficulty in studying all curriculum studies units such as English, Pakistan Studies and mathematics and Science. During the year of my action research there were a few students who felt they would face difficulty in other subjects but they wanted to accept the challenge of studying the General Science Curriculum.

Due to the reasons mentioned above, most of the student teachers had weak Science content knowledge.

After identifying the problem and its reasons, I started working on finalizing the strategy which could be used to help student teachers enhance their Science content knowledge. For finalizing the strategy, I kept in mind the two major factors given below:

1. I knew I was working with the adults. Teaching adults is different from teaching children. Adult learning requires an environment of openness and respect. Adults accept challenges of the given task, if they have realized the importance of that particular task. They want to use their own experiences and examples of others to solve any problem which they have encountered. As Engalls (1976) asserts, adults see themselves as capable of self-direction and desire others to see them in the same way. Adults enjoy planning and carrying out their own learning exercises. Adults want to be involved in evaluating their own progress towards self-chosen goals.

2. I was planning to carry out my action research with student teachers. I had to keep in mind that educational institutions for teachers put more emphasis on pedagogical knowledge rather that on the subject content. It is expected

> that a focus on subject content would have occurred prior to their taking this unit. Therefore, the anticipation of the teacher is that any focus on content within the unit would be largely in relation to pedagogical approaches to the transfer of content knowledge.

For the above mentioned reasons I had to be careful while choosing the strategy for helping student teachers to enhance their Science content knowledge. The literature reviewed (such as Barrows, 1984; Norman, 1988; Walton & Matthews, 1989; Duch, 1995; Miller, 1996; and Chappell & Hager, 1995) revealed how other researchers have conducted research which is similar to this one and is conducted in the relevant context. To find out the appropriate method which could satisfy the needs of student teachers, I consulted a number of pieces of literature. After a thorough study of various techniques of teaching and learning and considering all major issues involved in working with student teachers, I decided to use Problem Based Learning (PBL) as a method for helping student teachers enhance their Science content knowledge.

Stage 2: Action research cycles

On the basis of facts about the situation and review of literature, action research cycles were planned. The first cycle was planned through reconnaissance and the subsequent cycles were developed from the result of the previous cycle. My action research had three cycles. The duration of each cycle was almost two weeks of various numbers of sessions, at least three sessions of 1 hour per week. A detail of the cycles is given in section 3.

The action research team

This action research was a combined effort of my team members who were chosen to conduct the research study. My action research team included my mentor, my critical friend (an experienced colleague from the same context where action research was conducted), a school carpenter (who provided information to the student teachers about various kinds of wood), fourteen student teachers and myself.

Role of cooperative learning in problem solving activities

Well-defined or well-structured problems can be solved individually but ill-defined or ill-structured problems can better be solved in small groups (Killen, 1996). As I used ill-structured problems in all three cycles of my action research, I used a cooperative learning strategy throughout the research. According to Cinelli (as cited in Killen, 1996), this strategy encouraged students to work together to maximize learning.

Limitations of the research method

This action research had the following limitations:

- In the beginning of my research, students were not trained for problem solving. Therefore, most of them struggled with the given problems (particularly with the problems given during the first cycle) and acquired more help from me for planning procedure for solving the problem.
- The purpose of the research study was to enhance the Science content knowledge of student teachers which included Biology, Chemistry and Physics sections of the Science course; therefore, ill-structured problems were designed covering all three areas. Because of this, those students who were not interested in particular sections were not motivated.
- Most of the problem solving activities were done in groups, therefore slower learners seemed over-dependent on others.

Report on the action research

According to Killen (1996), a problem can be defined as any situation in which some information is known and other is unknown. It is something that gives rise to uncertainty or something that is hard to understand. According to Bransford and Stein (as cited in Eggen & Kauchak, 1997), a problem exists when someone is in a state that differs from the end state and there is some uncertainty about reaching the goal or end state.

Types of a problem

There are two types of problem, namely, well-defined problem and ill-defined problems. According to Dunkle, Schraw and Bendixon (as cited in Eggen & Kauchak, 1997) and Ormrod (as cited in Eggen & Kauchak, 1997), a well-defined problem is one in which the goal is clear and paths to a solution are known or can be easily accessed. An ill-defined problem is one in which the goal is unclear and paths to a solution are unknown. Well-structured problems are solved by using algorithm (fixed rule and procedure) whereas ill-structured problems are solved by using heuristics (general rules) (Good & Brophy, 1986). Some common heuristics identified by Eggen and Kauchak (1997) include: (a) trial and error (picking up a solution and see how it works (b) means-end analysis (breaking down the problem into sub goals) (c) working backward (keeping more resources than required) (d) drawing analogies (comparing unfamiliar problem with the rules).

Problem-Based Learning

A general problem solving strategy is usually guided by realistic problems (the problems from the real-life) or authentic problems (Woolfolk, 1998) and is called the Problem-Based Learning (PBL). Barrows (1984) defines PBL as a teaching method which stresses problem solving activities as a means to encountering and applying knowledge. Bridges (1992) asserts that PBL is a set of problems such as simulation, ethical dilemmas, case studies, medical diagnoses or decisions, legal disputes, public policy issues and so on as the framework for student learning.

In order to maximize the outcome of the PBL, students are advised to work in cooperative groups most of the time. Cooperative learning effects positively on student motivation and student achievement. Students working cooperatively can remember and implement the problem solving strategy effectively. Problems taken from the real world increase students’ motivation and achievement (Johnson & Johnson; Sharan & Salvin, as cited in Nichols, 1996; Duren & Cherrington, as cited in Killen, 1996). According to Boud (1985), Boud and Feletti (1991) and Woods (1985), PBL and other forms of cooperative or active learning have certain common feature. The distinction between them is blurred but an essential component of PBL is that content is introduced in the context of complex real-world problems. Duch (1995) states that those who use PBL as a method of learning are convinced that learning is a discipline within the context in which it occurs as such enhances students’ learning that is ability to understand and apply what is being learned.

According to Engel (as cited in Chappell & Hager, 1995), proponents of PBL suggest that it serves two major and distinct purposes. The first is concerned with the practice and development of a number of crucial competences which includes reasoning critically and creatively, making reasoned decisions in unfamiliar situations, appreciating others' point of views and undertaking appropriate remediation after identifying strengths and weaknesses. Secondly, PBL meets appropriate conditions for effective adult learning. That is, active learning through posing own problem and seeking for a particular solution; integrated learning; learning for understanding through appropriate opportunities of self-reflection on educational experiences; and through continuous feedback linked with the opportunities to practice the application of what has been learned.

Because of its great advantages, PBL is becoming popular in various scientific as well as non-scientific educational institutes throughout the world, for instance, in medical school (Barrows, 1984; Norman, 1988; and Walton & Matthews, 1989), Science courses (Duch, 1995), history courses (Miller, 1996) and professional education (Chappell & Hager, 1995).

Using Problem-Based Learning to enhance student teachers' Science content knowledge

I considered PBL to be suitable for adults because it puts emphasis on their learning rather than on the teacher's teaching. Secondly, I knew that in this method, the focus on content would be largely in relation to pedagogical content knowledge. This includes: how to solve a problem; how to utilize available resources effectively in gathering and manipulating data; how to analyze and evaluate the process and result using critical thinking and reflective practice. It also includes: how to work in groups as well as individually; how the group members can effectively use each others' expertise; how to plan and implement the procedure; how to present the work effectively. Bhatia and Bhatia (1992) call problem solving a reflective thinking or reasoning. Skills such as focusing skills, information gathering skills, organizing skills, analyzing and integrating skill and evaluating skills, according to Killen (1996), are the core skills which need to be developed in students if problem solving is used as a teaching strategy.

Throughout the action research I used the procedural steps for problem solving given by Killen (1996). However, in some places, by looking at the consequences of my planned actions, I merged some ideas given by other researchers in the main procedural format. As Bound and Feletti (as cited in Chappell & Hager, 1995) state, "There is no single view of problem-based learning, indeed the conception will vary in practice according to the type of profession, the nature of the overall professional education programme, the time available, and preliminary skills of the group" (p. 2).

Action Cycle

The first cycle of the action research had six different sessions.

Group formation

To ascertain the problem solving abilities of the student teachers, the first step in the research process was to divide them into three groups of mixed ability without critically examining their previous performance during Science classes.

Assessment of the group work

To assess the performance of each member in his/her group as well the performance of each group, I used four strategies which included: (i) An observation sheet which I filled after observing students working in their groups; (ii) Discussion with students about their group work. (iii) Students' individual reflections; (iv) Group files in which the students kept the record of their planning and procedure of problem solving, information gathered by them and the reflection sheets of each member.

Procedure of the first cycle

(a) One ill-structured problem was prepared for all three groups.

(b) Students in their groups had to identify the major elements and the hidden assumptions in the given problem.

(c) Students needed to rate the identified elements on a five point rating scale starting from extremely important to not important.

(d) After rating the identified elements in the problems, students needed to generate ideas for solving the given problem by using brainstorming, mind mapping or any other appropriate method.

(e) Students then had to evaluate their ideas for solving the problem by discussing acceptability (the extent to which the idea was feasible to use); and originality (the extent to which the ideas could provide an elegant solution). On the basis of this discussion the student teachers decided to accept or reject ideas for solving the problem.

(f) The next step involved students' planning the procedure for solving the problem. This plan included identifying what kind of information was required to solve the problem, where they could find the information, who could find information for them, when they would find it and how they would present the solution to the whole class.

Implementing the plan and observing the activities

In the beginning, all the student teachers focused on the outlook of the problem. They took the problem as if it was related to carpentry work and furniture which they felt had no use in their studies. However, after keeping them focused on the essence of the problem they began to identify the hidden assumptions of the problem. They were asked to begin by answering, "How do trees grow strong?" Slowly and gradually they started thinking in terms of the effects of soil, water, climate, age of a tree, quality of seeds and so on. The performance of each was observed and recorded by using a checklist.

During the last session students presented their solution in front of the whole class. All three groups performed reasonably well. The main topics which covered by all three groups included: suitable trees for making furniture; identifying the types of tree with the help of physical properties of a tree; favourable conditions for the growth of different trees; effects of age on the strength of any tree; measuring the age of any tree; identifying the age and the effects of various climatic conditions on a tree by observing its log. There was a question and answer session at the end on each presentation.

Reflecting on cycle 1

A very slow but gradual improvement was seen in student teachers' learning and development of problem solving skills. One wrote in her reflection, "Until last class I was really confused and the task was not clear to me, but today it makes sense to me that what (sic) we are doing" (Student A, April 1, 2003). Some students realized that the problem solving activities were enhancing their high order skills. For example, one student's reflection noted, "I feel that my reasoning skill is increasing" (Student B, April 1, 2003).

Student teachers were able to identify most of the objectives of the problem-solving activity notably:

- To enhance problem-solving skills.
- To relate classroom teaching with daily life.
- Appreciating active learning approach.
- To enhance student teachers' reasoning skill.
- To evaluate how student teachers work in groups.
- Extensive reading and learning about the plants and trees.
- To appreciate the use of various sources for problem solving.

Satisfactory result of the problem solving activity

Student teachers enhanced their understanding of trees by gathering information about them from a number of sources. They went beyond the textbook to acquire knowledge about various element of the problem given to them. In terms of the students' pedagogical skills, this problem solving activity helped them to enhance their research skills such as planning, organizing, data gathering, analyzing skills and decision making skills. They shared their prior knowledge in groups to solve the given problems and contributed in gathering information in order to solve the problem.

Unsatisfactory result of the problem solving activity

In spite of many positive effects of the problem solving activities, there were a great number of negative points which I noticed during this cycle. These included:

- There was lack of motivation to work on problem solving activities.
- Some of the student teachers could not understand the problem therefore could not identify hidden assumption of the problem.
- Some groups did not work according to the plan they had developed to solve the problem.
- Some student teachers were unsure of the information to be searched.
- Some student teachers were over dependent on other students.

- Some student teachers exhibited a tendency to rush towards a solution without fully understanding the problem.

  Some unsatisfactory results are explained below in detail.

(a) Tendency to take the easiest path

Most of the students wanted to take the easiest path to solve the problem. Therefore, they decided just to gather information by interviewing any carpenter. They did not realize that a carpenter could not provide information about all apparent elements as well as hidden assumptions about the problem. Nor did they consider that the information provided by the carpenter could have been incorrect and that the authenticity of information provided by a primary source cannot be confirmed unless s/he has consulted other primary or secondary sources. The reason behind this could be a lack of experience in defining problems. Hayes asserts that understanding or identifying a problem in a given statement is not simple and straightforward. In fact, it is one of the most challenging aspects of problem solving because it requires creativity, persistence and willingness to avoid committing to a solution too soon (Hayes, as cited in Eggen & Kauchak, 1997).

As the student teachers were not sure of what information they were expected to find and where they could find that information, they exhibited a lack of motivation towards solving it. One student's reflection acknowledged that unless she really understood the problem she was not interested in solving it and suggested exploring an another area of enquiry other than wood. Killen (1996) suggests that "Unless students are interested and believe that they can solve the problem they may be reluctant to try" (p. 102).

(b) Lack of motivation among student teachers

Killen (1996) holds motivation as the key element in problem solving and the student teachers lacked motivation in the initial stages of the search. My reflection noted that the problem given was not stimulating for most of the student teachers because it was quite difficult for them to identify the hidden assumption in the problem due to its straightforward language. As one of the student teachers wrote in her reflection, "Although it was an interesting activity yet most of the time it was difficult to understand…There should be something else for giving knowledge about log (Student teachers' reflection on April 1, 2003). Four possible reasons presented themselves as explanation.

(i) Considering the problem solving activity as a waste

The action research commenced after the content of the Science course had been covered with the student teachers. Therefore, for some of them problem solving was an unnecessary activity. They took it as a burden and an extra task which was prepared to keep them busy. One student teacher reflected that she considered the problem solving activity boring and a waste of time (Student teachers' reflection on April 1, 2003).

(ii) Considering the problem solving activity as a part of the routine work

Some student teachers were uninterested as they found it like a routine assignment. For example, one stated her reflection, "Nothing is unusual, for further information we will have to go to the library" (Student teachers' reflection on April 1, 2003).

(iii) Considering the problem solving activity as useless activity

Some student teachers took it as a revision task and a beneficial activity to prepare for the examination; others found it suitable for finding out information about any interesting topic. Eccless and Wigfield found that interaction of students' expectations and their valuing of the given task predict their motivation. Those students whose expectations are high and also value the task are most motivated (Eccless; Wigfield; & Wigfield, as cited in Martin, 2002).

Revision work had no value for the students who were not appearing for the local university examination as the activities would not affect their assessment grades so problem solving at the end of the course was not motivating factor. As Martin (2002) asserts, when students see the utility or importance of what they are learning, they tend to engage more in these subjects and achieve at a higher level.

(iv) Unavailability of sufficient time to complete the problem solving activity

Students found it difficult to spare some "extra time" to use more than two or three sources for gathering information about the given problem. As one student reflected "These are the interesting activities but we don’t have extra time…Nobody in our group is ready to go to the timber market…our group members are only visiting the carpenter and library and using their personal experiences to solve the problem" (Student teachers’ reflection on April 1, 2003). Unavailability of sufficient time to complete any task increases frustration. It does not allow the space for ideas to grow in students' mind.

Action Cycle 2

Planning for cycle 2

The result of the first cycle sent me back to the drawing board to re-plan and plan the next step.

(a) Grouping students

During the first cycle three distinct kinds of students were evident and I simply called them high, middle and low achievers. High achievers were more focused, planned and ready to accept the challenges of the given task. Middle achievers were reasonably good in their performance and developed plans and selected strategies but they were unsure whether or not their plans were workable or what could be the expected solution. Low achievers were inactive throughout the task and were dependent on other students while working in groups. They were not ready to take responsibility for their learning. This contrasted with Killen's (1996) findings that, "In problem-based lessons, the familiar student question, why do we need to know this? is often replaced with what do we need to know? as students accept responsibility for their own learning" (p. 102).

According to Covington and Omelich (as cited in Martin, 2002) some students can effectively deal with academic stress whereas others cannot. They categorize students into three typologies. (a) Success-oriented students (student who tend to be positive and are not debilitated by setbacks) (b) Failure-avoidant students (students who tend to be motivated by a fear of failure) and (c) Failure-accepting students (those students who display helpless pattern of motivation). My categories of high achievers, middle achievers and low achievers could easily be replaced by the categories given by Covington and Omelich.

To avoid dominancy and over-dependency and ensure good working relationships among students, Cherrington (as cited in Killen, 1996) suggests pairing high ability students with average ability students and similarly low ability students with average ability students. Keeping this in mind I planned to divided middle achievers into two halves and rearrange groups by grouping middle achievers with both high and low achievers.

(b) Explaining the purpose of problem solving activities

To increase the level of student teachers' motivation, I planned to explain the purpose of the problem which I intended to use during the second cycle (Killen, 1996).

(c) Enhancing self-efficacy among student teachers

Success oriented students have a strong sense of self-belief or self-efficacy (Bandura, as cited in Martin, 2002) and perform very well in academic activities. Bandura (as cited in Zimmerman, 2000) states, "there is evidence that self efficacious students participate more readily, work harder, persist longer and have fewer adverse emotional reactions when they encounter difficulties than do those who doubt their capabilities" (p. 86). To help the student teachers enhance their self-efficacy, I decided to create an environment of support, appreciation and encouragement so that all the students might experience success. Such an environment would also help them to be patient and avoid rushing towards a solution which, according to Wang and Hildebrandt (as cited in Eggen & Kauchak, 1997) is a characteristic of novice problem solvers of all ages. They usually jump into a solution before they have clearly understood the problem.

(d) Using student teachers expertise

During my informal discussion with the student teachers I found that most of them had some background knowledge and experience in the Biology section of the General Science course. Very few of them had background knowledge and experience in other two area of General Science (i.e. Chemistry and Physics). Therefore on insights given by Schuelh (Schuelh, as cited in Killen, 1996), I decided to prepare problems from the Biology section once again as I did for the first cycle.

Implementing the plan and observing the activities

(a) Providing illumination and incubation time

They were asked to read the problem carefully and then keep it aside without working on it during their teaching practicum. The purpose behind this was to allow time illumination (Wallas, (as cited in Good & Brophy, 1986) or moments of silence and solitude so that best ideas for might emerge. Wallas asserts that illumination and incubation is a period of reflection and analyzing. These are experiences which a person suddenly becomes aware of a solution. It may be unconscious and may occur during sleep.

(b) Re-introducing the problems

When student teachers came back from teaching practicum they were already familiar with the task. I gave to each group a copy of their problem once again and answered any questions they had. In this second cycle, I gave a different problem to each group (Appendices 1b, 1c, 1d). However, all the problems were case studies and medical diagnoses (based on diseases). The reason behind giving different problems to different groups was to cover wide area of information about diseases.

(c) Students' reaction

The students' reaction towards the problems was positive as they looked quite familiar with their topics. Although they were told to not to spend so much time in solving the problem during their school experience, but knowingly or unknowingly, most of them were working on the problem.

(d) Breaking down the problem into small questions

To address the issue the first cycle issue of taking short cuts to solve the given problem, I broke down the main problem into small questions and gave them guidelines for identifying the major elements in the problem. This had the element of training student teachers to solve an authentic problem (real-life problem).

(e) Preparing a timeline for various problem solving activities

During the first cycle student teachers were not well planned and until the day of the presentation they were working on the solution. During the presentation the students were unaware of the tasks of their group members. The solution presented by each group was not prepared through consensus, therefore only a few students from each group knew about the solution. To avoid this problem in the second cycle, I asked the student teachers to prepare a timeline for various activities that they have planned to perform in order to solve the problem. A list of some proposed activities was given to them. This timeline would remind them about major activities such as time for completing the required information, sharing their work with each other, discussing the solution and preparing a presentation and summary sheet.

(f) Avoiding dominancy and over-dependency

An additional problem during the first cycle was over-dependency. In the second cycle I encourage student teachers to participate equally in the group tasks. To assess their performance I gave to the students a guided reflection sheet. Apart from the reflection on various activities student teachers also had to mention their roles as group members in the provided reflection sheet.

Reflecting on cycle 2

The student teachers worked according their prepared plan and performed very well. Two of major achievements during this cycle were as below:

(a) High motivation among students

During my informal discussion with the groups I noticed that student teachers were quite happy with the grouping. Most of them also felt that the instructions this time were very clear therefore they knew what was expected of them. They felt that they had ample time to search for the topic. They realized that the problem solving activity expanded their knowledge about disease. For example, one of the student teachers acknowledged that the task was very interesting. Consulting various books, discussing and finding details of each disease expanded her knowledge about it. She realized that she had learnt a new method of teaching and learning. Another student teacher held similar views. She stated, "It was a nice and exciting topic. All the members enjoyed a lot…I was interested to know about different kinds of diseases because many were unknown and had such symptoms which really amazed me". Another student appreciated the use of various sources by her group to find the solution to the given problem and the current information provided by the other groups. In her reflection she wrote, "We searched from the Net and medical books. We even tried to use different aids while presenting our task…Overall it was informative, interesting and as new recent disease 'SARS' was discussed so getting the information from different groups increased our knowledge and made us up to date".

(b) Moving from functional fixedness to divergent thinking

For the problem given in the first cycle, the students focused on the outlook of the problem and considered it as the problem on carpentry work therefore they could not identify the hidden assumptions. Eggen and Kauchak (1997) named this tendency of focusing on one solution to a problem, convergent thinking, whereas Duncker (as cited in Eggen & Kauchak, 1997) has named this the tendency of objects having only one function, as functional fixedness. In contrast with convergent thinking, the student teachers during the second cycle were divergent in their thinking. For example according to one particular group, Elina (name used in the problem) could be suffering from epilepsy, migraine, tetanus or tourette syndrome. Instead of working on one particular disease this group was working on various similar diseases. William (as cited in Killen, 1996) named this students' behaviour (which is associated with higher order thinking and is the ability to produce a large number of ideas, products and responses) as fluency.

Action cycle 3

The result of the second cycle helped me in planning the third cycle.

Planning for cycle 3

(a) Grouping students

I planned to use the same strategies for the third cycle but with only two groups to work on the problem. There were two reasons behind it. Firstly, those student teachers who were not appearing for examination had to work on an environmental project (a project designed by method teachers, other than problem solving, to assess IGCE students). Secondly, I wanted students to learn problem solving skills and how to critically examine or evaluate the procedure of problem solving so that they may become successful problem solvers in future. For this reason those student teachers who were not appearing for the examination were grouped together to perform a devil's advocacy role (Schweiger, David, Sandberg, William & James, 1986). There work was to critically examine the plan and procedure prepared by other two groups.

I purposely grouped those students together who exhibited insufficient background knowledge of Physics during my classes so that a simpler problem was given to them.

(b) Considering domain-specific knowledge of students

I observed one student teacher had a good knowledge of Chemistry and Physics as her method subject was Chemistry. Chi et al. (as cited in English, 1992) state, "It is well established fact that individuals with a comprehensive knowledge of a given domain will outperform those with the limited knowledge" (p. 203). Therefore, I kept the Chemistry student in the devil's advocacy group. I thought that she would analyze the procedure by using her domain-specific knowledge. Other members of the devil's advocacy group would work as co-workers. Once the procedure for problem solving would prepare properly, solution would not be difficult.

Implementing the plan and observing the activities

(a) Introducing the problems

One of the two problems introduced to the groups was a scenario taken from the history book and was based on the simple and compound machines. This was a well known topic therefore I gave it to the group with insufficient knowledge about Physics topics. The other problem which was based on Archimedes Principle and was comparatively difficult one was given to the group with sufficient knowledge about Physics topics.

(b) Devil's advocacy

When both the groups had planned the procedure and had gathered some ideas to solve the problem, the group responsible for providing devil's advocacy criteria evaluated the plans and procedures prepared. They gave a report to both the groups who were asked to revise the plan by considering the suggestion given in the report. Each group was then asked to solve the given problem by using the revised plan.

(c) Dividing devil's advocacy group into two sub-groups

When the devil's advocacy group had completed their analysis they set about completing their environment project after which they were divided into two sub-groups to join other two groups.

(d) Students' presentations

On the day of the presentation, both the groups presented their solution. They covered a number of topics such as pressure, pressure in liquid, buoyancy, density of liquid, counter weight, ramp, lever, inclined plane, pseudo pulley and screw. There were still many areas to be improved. For example the group working on the problem based on simple and compound machines could not explain the measuring instruments used by the Egyptians to get the accuracy up to 1 millimeter nor how effectively the modern technology could be used to construct the pyramids.

Reflecting on cycle 3

As the student teachers were grouped in two groups according to their domain-specific knowledge, the difference in their performance during the third cycle was almost predetermined by my planning. A very interesting result came up after this cycle. The student teachers who had weak background knowledge of the subject utilized this activity to improve their content knowledge. One student reflected on her realization that her basic knowledge of Science was weak, therefore during these problem-solving sessions she tried to overcome her problem by gathering information and by discussing various topics in the groups. The result was her determination to gain more content knowledge about her subject. Another student acknowledged that she was totally unaware of Physics content but through problems solving sessions she had the opportunity to learn something about simple and compound machines. Student teachers with sufficient background knowledge concentrated on their process and skills of problem solving to help them understanding their leadership qualities and skills of organizing information. Another student teacher wrote that these sessions helped to develop her research skills.

Conclusion

Problem solving activities help student teachers to enhance their Science content knowledge. The experience of problem solving activities also enhanced students' focusing skills, data gathering skills, critical thinking skills, reasoning skills and evaluating skills. PBL helped student teachers examine their own abilities and weaknesses. Most of the student teachers acknowledged that the problem solving sessions helped them to know their strengths and weaknesses. For example, one of the student teachers in her final reflection on PBL wrote that she had a tendency to jump to the conclusion without understanding the problem properly. However, during problem solving activities, she practiced going into depth and solving the problem after considering various factors involved in the problem which, in turn, improved her problem solving skill (Student C, June 5, 2003). Some student teachers felt that they were not good readers, but these problem-solving sessions made them consult various books. They were surprised to see that books had interesting information about various topics. The student teachers realized that their content knowledge was quite weak but these problem-solving sessions gave them an opportunity to improve their Science content knowledge (Student teachers' reflection on June 5, 2003).

Student teachers views about various problems were highly dependent on the level of their understanding of the problem, their problem solving skills and their prior knowledge about the topic. For example, a student teacher who was working on simple and compound machines during the third cycle wrote that she was very happy to experience problem solving activities. She further explained that she liked the second problem very much because that problem was easy for her to understand. She got confused while solving the third problem (Student teachers' reflection on June 5, 2003).

Clear and precise instruction can help student teachers understand the problem well and to solve it. Well planned supervision of the problem solving activities increases student teachers' motivation. Most of the student teachers suggested that there should be more clear instructions about the problems. Some of them appreciated the method of keeping the record of each session and providing reflection sheet to evaluate the performance of each group. However, they suggested that these learning sessions should be well instructed and well supervised.

The action research process helped the student teachers to improve their content knowledge and to enhance their high order thinking and reasoning skills. However, it would be important to consider the following aspects in planning any next action of the research process.

- Instead of solving one problem each time, the student teachers must be given some intensive work to train them in the following aspects:
    - Identification of major elements and hidden assumption in various well-structured and ill-structured problems.
    - Generating various ideas to solve the given problems.
    - Planning procedures for solving problems. This training might help them to solve any given problem more skillfully.
- In order to help student teachers to use PBL effectively for enhancing their Science content knowledge, continuous problem solving activities should be provided for them. It will be effective if the whole Science syllabus is developed on the bases of PBL rather than having just a few sessions of problems solving at the end of year.
- All the problems used during the action research were deliberately formulated by the researcher for student teachers to enhance their Science content knowledge. However, in future the student teachers can also be given opportunities to formulate problems for themselves. In this way problem solving can be used as a self-learning technique.

- Problems need to be presented to student teachers by using concrete material with the written scenarios rather than giving problem just in writing. This will increase a sense of motivation among student teachers.

There are some essential prerequisites for problem solving which include, skilful planning of problem solving sessions, basic training of student teachers for problem solving and appropriate techniques for monitoring and supervising student teachers' performance. With the provision of essential prerequisites for problems solving activities, PBL can enhance student teachers' Science content knowledge more effectively.

Reference

Barrows, H. (1984). A specific problem-based, self-directed learning method designed to teach medical problem-solving skills and enhance knowledge retention. In H. Schmidt & M. deVolder (Eds.), *Tutorials in problem-based learning.* Netherland: VanGorcum. Retrieved March 25, 2003, from http://www.bu.edu/wcp/wcp/Papers/Teac/TeacLitt.htm.

Bhatia & Bhatia (1992). *The principles and methods of teaching.* Delhi: Doaba.

Boud, D. & Feletti, G. (Eds.) (1991). *The challenge of problem-based learning. St. Martin's Press, N. Y. Retrieved March 25, 2003, from http://www.udel.edu/pbl/dancase3.html.*

Bouma, G. (1996). *The research process.* (3rd ed.). Singapore: Oxford University Press.

Burns, R. (1997). *Introduction to research methods.* (3rd ed.). Melbourne: Longman.

Chappell, C. S. & Hager, P. (1995). Problem-based learning and competency development. *Australian Journal of Teacher education. 20* (1), 1-7.

D. Boud, (Ed.). (1985). Problem-based learning for the professions. Sydney. HERDSA. Retrieved March 25, 2003, *from http://www.udel.edu/pbl/dancase3.html.*

Duch, B. (1995). Problem based learning in Physics: the power of students teaching students. *About teaching, 47,* 6-7. Retrieved March 25, 2003, from http://www.bu.edu/wcp/wcp/Papers/Teac/TeacLitt.htm.

Eggen, P. & Kauchak, D. (1997). *Educational psychology: Window on classroom*. (3rd ed.). New Jersey: Merril.

Engalls, J. D. (1976). *Human energy: The critical factor for individual and organizations.* Unknown: Addison-Wesley.

English, L. (1992). Children's use of domain-specific knowledge and domain-general strategies in novel problem solving. *British Journal of Educational Psychology. 62,* 203-216.

Gay, L. R. (1992). *Educational research: Competencies for analysis and application.* (4th ed.). Sydney: Maxwell Macmillan International.

Good, T. L. & Brophy, J. E. (1986). *Educational psychology: A realistic approach.* New York: Longman.

Henry, C. & Kemmis (1985). A point-by-point guide to action research for teachers. *The Australian Administrator. 6 (4), 1-4.*

Killen, R. (1996). *Effective teaching strategies: Lessons from research and practice.* Went worth fall: Social Science Press.

Martin, A. (2002). Motivation and academic reliance: developing a model for student enhancement. *Australian Journal of Education. 46* (1), 34-49.

Miller, M. (1996). Introducing art history through problem-based learning. *About teaching, 50,* 3-3. Retrieved March 25, 2003, from http://www.bu.edu/wcp/wcp/Papers/Teac/TeacLitt.htm.

Norman, G. (1988). Problem-solving skills, solving problems and problem-based learning. In H. Schmidt, M. Lipkin, M.W. Devries, & J. M. Greep (Eds.). *New directions for medical education.* New York: Springer Verlag. Retrieved March 25, 2003, from http://www.bu.edu/wcp/wcp/Papers/Teac/TeacLitt.htm.

Nichols, J. D. (1996). Brief research report: the effects of cooperative learning on student achievement and motivation in a high school geometry class. *Contemporary Educational Psychology. 21,* 467-576.

Schweiger, David, M., Sandberg, William, R., & James, W. R. (1986). Group approaches for improving strategic decision-making: A comparative analysis of dialectical inquiry, devil's advocacy, and consensus. *Academy of Management Journal, 29* (1), 51-71. Retrieved March 25, 2003, from http://www.vta.spcomm.uiuc.edu.

Walton, H. & Matthews, M. (1989). Essentials of problem-based learning. *Medical education. 23,* 542-558. Retrieved March 25, 2003, from http://www.bu.edu/wcp/wcp/Papers/Teac/TeacLitt.htm.

Woods, D. (1985). Problem-based learning and problem-solving. In D. Bound (Ed.). *Problem-based learning for the professions.* Sydney. HERDSA, 19-42. Retrieved March 25, 2003, *from http://www.udel.edu/pbl/dancase3.html.*

Woolfolk, A. E. (1998). *Educational psychology* (7th ed.). Sydney: Allyn and Bacon.

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology.25,* 82-91.

Correspondence

Martin Thomas

Email: thomasmartin_900@yahoo.com