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Developing Preservice Teachers' Pedagogical Reasoning Ability

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Abstract

Teachers not only need to develop a knowledge base for teaching, but also should be able to make reasoned decisions regarding their classroom science teaching. Preservice teachers need opportunities to begin developing their pedagogical reasoning ability as part of their undergraduate education so that science teaching in primary schools is based on sound reasoning. This paper, using a case study methodology, reports on the initial pedagogical reasoning ability of second-year preservice primary teachers. By completing a problem-based science education topic, these preservice teachers had the opportunity to explore all stages in the pedagogical reasoning process. Preservice teachers initially demonstrated limited pedagogical reasoning ability, but as a result of the framework provided in the problem-based approach, they were able to refine their reasoning ability. Through a combination of group work and individual research, the preservice teachers were able to integrate their science knowledge, curriculum knowledge and knowledge of learners and apply this to a peer-teaching situation and in the process develop their pedagogical reasoning skills.

In science teacher education programs, the time available for the professional education of preservice primary teachers is typically limited. Consequently, these programs are placed in a dilemma when developing preservice teachers' science content knowledge, curriculum knowledge, and an understanding of pedagogy as well as the ability to teach primary science. Past research has already identified the weak science backgrounds of primary science teachers and that this deficiency leads to a lack of confidence to teach primary science (Appleton, 1992; Jeans & Farnsworth, 1992). One response to this situation was to recommend an increase in the amount of time spent in developing preservice teachers' science knowledge so that the teaching of science in primary schools would be improved (Speedy, 1989; Ministerial Task Group Reviewing Science and Technology Education, 1992). However, this recommendation has been questioned; for example Appleton (1992) found that an increase in preservice teachers' scientific knowledge did not necessarily change their perceptions, which were often negative, of science and their ability to teach science.

Rather than concentrate preservice education on the development of science content knowledge, an alternative approach for improving the ability of preservice teachers to teach primary science is to focus on the development of their pedagogical reasoning ability. Teachers not only need to develop a knowledge base for teaching science, but also need to use their understanding of science content, curriculum and the learner when making decisions regarding their classroom teaching. Shulman (1987) has described this decision-making as pedagogical reasoning and proposed six stages in his model of the process that are shown in Figure 1.

1.	Comprehension	Teacher understanding of the ideas to be taught and the educational purposes of the topic/subject.
2.	Transformation	Comprehended ideas are transformed by the teacher for use in a particular classroom setting. This includes critical interpretation of text materials, identifying ways of representing ideas, selecting appropriate teaching methods, adapting and tailoring ideas to the particular class group.
3.	Instruction	The act of teaching. This includes organising and managing the class and students, presenting clear explanations, interacting with students, questioning and evaluating.
4.	Evaluation	This includes both the evaluation of student learning and the teacher's own teaching performance, materials employed, etc.
5.	Reflection	The review of the events and accomplishments that occurred during the lesson.
6.	New Comprehension	New understanding of subjects, learners, purposes and pedagogy through the process of teaching.

Figure 1. Six stages of a model of pedagogical reasoning (Wilson, Shulman, & Richert, 1987).

Various authors have recommended that pedagogical reasoning be given a higher priority in teacher education programs (Shulman, 1987; McDiarmid, Ball, & Anderson, 1989; Kennedy, 1990; Reynolds, 1992). These programs should encourage preservice teachers to develop their reasoning ability and to apply this to teaching situations. This process is important so that teachers will learn to use their knowledge effectively in making decisions on particular actions they will take when teaching (Fenstermacher, 1986).

Through preservice teacher education programs, Reynolds (1992, p. 27) believes that, amongst other abilities, beginning teachers should have developed (1) knowledge of the subject matter they will teach, (2) knowledge of strategies, techniques, and tools for creating and sustaining a learning community, and the skills and abilities to employ these strategies, techniques, and tools, (3) knowledge of pedagogy appropriate for the content area they will teach, and (4) the disposition to reflect on their own actions and students' responses in order to improve their teaching, and the strategies and tools for doing so. In developing their pedagogical reasoning, it is necessary to consider the learning environment and the teaching approaches used. Mulholland and Wallace (1994) believe that a supportive, group focussed, cooperative learning environment is important to enable preservice teachers to feel comfortable in asking questions and acquiring a more meaningful understanding of the ideas discussed. Therefore, if pedagogical reasoning is to be developed in preservice teacher education, the teaching approach must consider the learning environment and allow preservice teachers to experience each of the reasoning stages, and integrate the knowledge required as part of this process.

In this study, the pedagogical reasoning ability of second-year preservice teachers was established at the beginning of and during a science education unit designed to encourage the development of all six stages of Shulman's pedagogical reasoning process.

Research Design and Methodology

Design of the unit

Shulman's (1987) pedagogical reasoning model provided the framework when designing the unit. To enable the preservice teachers to explore and build upon their existing pedagogical reasoning ability, a problem-based learning (PBL) approach (Boud & Feletti, 1991) was used. Initially, they were given a series of activities on either the topic magnets or air. They were required to trial the activities, and develop an understanding of the scientific explanation for these activities (*comprehension*). In addition to acquiring the understanding of the topic, they were to prepare some of their topic for teaching to a peer (*transformation*). After completing this peer teaching component (*instruction*), the preservice teachers were then to *evaluate, reflect* and develop *new comprehension* of the topic. To assist them, guiding questions for the six stages of pedagogical reasoning were provided in a journal prepared for this unit.

The problem for the preservice teachers which provided the context for their investigations was stated as:

> A colleague of yours has missed some work during the year on one of these topics (i.e., Magnets or Air). They are behind in their work and have asked you to help them catch up the work missed by going through the science ideas with them.

The journals kept by the preservice teachers consisted of questions which assisted them as they completed each of the pedagogical reasoning stages. Some of these journal questions and the corresponding pedagogical reasoning stage are illustrated in Figure 2. Preservice teachers were not given any formal instruction on the pedagogical reasoning model, and the terminology of comprehension, transformation and so forth was not used in any discussions.

To assist the preservice teachers in the comprehension stage, they were given primary science experimental activities and a series of questions relevant to the topic. This information provided the basis for the development of their science content and curriculum knowledge. For example, some of the questions which they were to investigate for the topic *magnets* were:

> How can magnets be formed?
> What materials are magnetic?
> What are some of the properties of magnets?
> What are magnetic fields?
> How can magnetism be destroyed?

The practical activities focussed on these questions, although the preservice teachers had to establish their understanding and explanation of a practical activity, and in doing so develop an answer to the questions posed in their topic. For example, in one activity they were to stroke an iron nail to form a temporary magnet, which was then tested for its magnetic properties. As part of this activity the preservice teachers were to establish an explanation for their findings, and through this process they were developing a response to the question "How can magnets be formed?" They were encouraged to consult reference material to develop their understanding of the activities they completed.

The preservice teachers established their groups each comprising three members for this problem-based unit. These groups were responsible for managing their investigations throughout the problem-based unit, and were given control of the learning environment to gain the required knowledge, and to discuss the aspects within the stages of pedagogical reasoning.

Comprehension
What do you know or understand in the topic you will be investigating?
Draw a concept map for your topic.
Which ideas do you fully understand?
Which ideas don't you understand?
What did you learn through these [practical] activities?

Transformation
How will these ideas be presented and explained to another person?
In what order would you present the ideas to this person? How will the science ideas be explained?

Instruction
How will you teach your topic to another person?

Evaluation
What aspects of the lesson went well?
What aspects did not go as well as expected?
How well were the ideas understood [by this person]?

Reflection
What changes would you make?

New comprehension
List all the ideas you now have and understand on the topic, and re-draw your concept map.

Figure 2. Examples of questions for the stages of pedagogical reasoning represented in the journal

The researcher (RP) was the lecturer responsible for teaching the PBL class group, and was a participant-observer in the program. However, as the PBL program was student-directed the researcher's primary role in this process was to facilitate the group process, and so a greater proportion of the time could be devoted to observation of the groups at work. In addition, this researcher was responsible for conducting all interviews and analysing the journals. This creates a possible limitation whereby students may have believed that they should respond in a more positive manner in both the interviews and the journal. In this case, the potential for any bias in the findings was reduced through the triangulation of data from various data sources.

Student Sample

The class group participating in this study consisted of 21 preservice teachers, comprising six males and 15 females who were enrolled in the Bachelor of Teaching (Primary). They had all completed a one semester science education unit. This class group was a subset of the total second-year science education cohort (n=104) and was one of five class groups enrolled in the subject. All preservice teachers were randomly assigned to these class groups at the beginning of each year. In this second-year science education unit, they participated in a two hour session once per week, the format of which was at the discretion of the lecturer teaching the subject.

Data Collection Methods

The class group formed the case study for this unit. Data were collected from four sources, namely, interviews, journals kept by the preservice teachers, field observations made by the researcher, and a survey questionnaire completed at the end of the problem-based unit. All members of the class group completed the journal and the survey questionnaire as part of the unit requirements. Semi-structured interviews were conducted with seven members, randomly selected from the sample group, at the beginning, and on completion of the problem-based unit. Interviews were audio-taped and later transcribed. All four sources of data ensured that some triangulation of data could be achieved when reviewing the results during the problem-based science education unit.

Data were analysed for evidence of the knowledge base for teaching and pedagogical reasoning of the preservice teachers. For the knowledge base for teaching, data were reviewed for evidence of the development of science content knowledge, knowledge of learners and curriculum knowledge. To establish the pedagogical reasoning ability of the preservice teachers, the data were reviewed in relation to the six stages of the reasoning process. As the preservice teachers were not aware of these categories for the analysis of the data, it was assumed that comments they made were representative of their views. At no stage during the PBL program were the preservice teachers given any formal instruction on the knowledge base for teaching or pedagogical reasoning process.

Results

Pedagogical reasoning ability of preservice teachers prior to the problem-based unit

Issues in relation to the pedagogical reasoning ability of the preservice teachers were explored through interviews with seven members of the class. The interviews focussed on two aspects: planning science lessons and teaching primary science. This discussion often centred on their primary science teaching experience from the first-year Bachelor of Teaching program. The issues are discussed in relation to the relevant categories of the pedagogical reasoning process.

Comprehension

The two main areas discussed by the group members interviewed were science content knowledge and knowledge of curriculum.

Science Content Knowledge

They considered that an understanding of science content knowledge was necessary to ensure that primary students obtained the correct scientific information (3 students), to be confident when they were teaching (2), and to be able to answer questions posed by primary students during the lesson (2).

The ability to answer primary students' questions during a lesson was considered important as these preservice teachers believed they should provide the correct science content information to students. Being able to answer student questions was viewed as an important aspect of their ability to maintain control of the science lessons: "If they ask you a question and you stand there going 'Oh, I don't know that one', then that demonstrates to the kids that you don't like science.

Then the kids think, 'Why are we doing it?' (Rebecca, Interview - 1.1/4). The ability to control the class contributed to one person's confidence to teach primary science: "You have to make sure you are confident enough because if you are standing out [at] the front and kids know that you don't know what you are going on about, you just lose control of the class" (Emily, Interview - 1.1/5).

For all interviewees, science content knowledge was an important factor in their ability to teach primary science, as this knowledge provided them with the confidence and understanding to discuss the science ideas in the classroom.

Knowledge of Curriculum

The preservice teachers believed their knowledge of curriculum materials was weak and still needed to be developed. Five preservice teachers had not reviewed curriculum materials for teaching; consequently their knowledge of curriculum was limited to either material supplied by the supervising teacher during their first-year School Experience Program, or to curriculum materials discussed as part of the first-year science education program. Mark's comment on the need for more information on curriculum resources was typical of the responses for the seven preservice teachers interviewed: "I would like to look at resources....I don't think many people know of all the recent scientific [curriculum] resources" (Mark, Interview - 1.1/4). It was evident that the seven interviewees were not aware of the extent, or variety of curriculum materials available, and had little experience in evaluating and adapting them to particular classroom settings.

Transformation

Lesson planning was either guided extensively by the supervising teacher, or was based on views of teaching from their own experiences. For example, Rebecca had minimal input into the planning of her science lesson as the planning process was directed by the supervising teacher in the school setting:

> The teacher told me the topic and I had to come up with the idea. The librarian looked up the book and she just handed it to me. Because I had a book and it explained it for me. It explained dispersal and everything and all I had to do was just go over it. (Rebecca, Interview - 1.1, pp. 2-3)

In another case, Tony's experiences as a student at both the secondary or tertiary level directly influenced the methods he used in planning and transforming ideas for the primary classroom. For example, Tony had discussed with a primary grade 5/6 the concept of density using the formula $D = M/V$ as he assumed primary students would understand the formula, and that this was appropriate when explaining the concept. When Tony was asked how he decided on this explanation he commented: "The way I explained it was the way I was taught in science [at secondary school] and the way you explained it [in first-year science education]" (Tony, Interview - 1.1/3). In these two cases, planning was guided from the observations of experienced teachers teaching the topic.

Five preservice teachers were still teacher-directed in their view of student learning and did not consider the prior understanding of the learner. Two preservice teachers recognised that students do have views which need to be identified, although one who recognised the need to assess prior knowledge was willing to accept student views at the beginning of his lesson, and then redirect the students toward the science ideas to be considered in the lesson.

These seven preservice teachers did not discuss the remaining four stages of the pedagogical reasoning process, and this could be attributed to their limited experience in teaching primary science. However, they identified a variety of areas which they believed required further development to improve their teaching of primary science. Five of the seven teachers were concerned with their knowledge of science content and their ability to explain science concepts: "It's simplifying...when you need a simple explanation like such and such change, and I'm trying to think of the physics explanation and I have to get that out of my head and think more like children" (Sally, Interview - 1.1/1). Planning of science lessons was also seen to be an area of weakness as Rebecca stated:

> I'm hopeless at planning. How to start. When we're having a sequence of lessons, I don't know where to start. And that's what messes me right up. Because I have all of these ideas and I think where are they going to go. I know last year, when I had planned one lesson, and when I wrote it out I realised that it should have been the other way round. (Rebecca, Interview - 1.1/5)

Other issues identified included developing their questioning skills and evaluation techniques, dealing with issues associated with instruction (e.g., group size, individual differences, control, time, materials, organisation) and critically evaluating science content, curriculum materials and children's ideas when planning to teach.

The Pedagogical Reasoning Considered by Preservice Teachers During the Problem-Based Unit

Comprehension

Preservice teachers were able to develop both their science content knowledge and knowledge of curriculum as part of this pedagogical reasoning stage. Concept maps drawn at the beginning and on the completion of the unit, in addition to comments made in the journal, were used to ascertain preservice teachers' science content knowledge.

Science content knowledge

The problem-based learning approach enabled all of the preservice teachers to develop their science content knowledge and build upon their prior knowledge in the topic. This was evident in the changes to the concept maps over the period of the problem-based unit. For example, Julie demonstrated little understanding of the concepts of "air" at the start of the topic. She listed the concepts of air resistance, air turbulence, what air consists of and air pressure as ideas she did not understand. Julie could not recall ever doing any work on "air" at either primary or secondary school. Her initial concept map (Figure 3) referred to only some of the key ideas relevant to the topic. Linkage statements were not evident in this initial map. However, when this map was compared with her final concept map (Figure 4) it was evident that further development of the concepts had occurred and linkage statements were now evident. She believed her understanding of "air locks [air taking up space], air pressure, what air consists of and what moving air can do" (Julie, Journal - 1/8) had all developed.

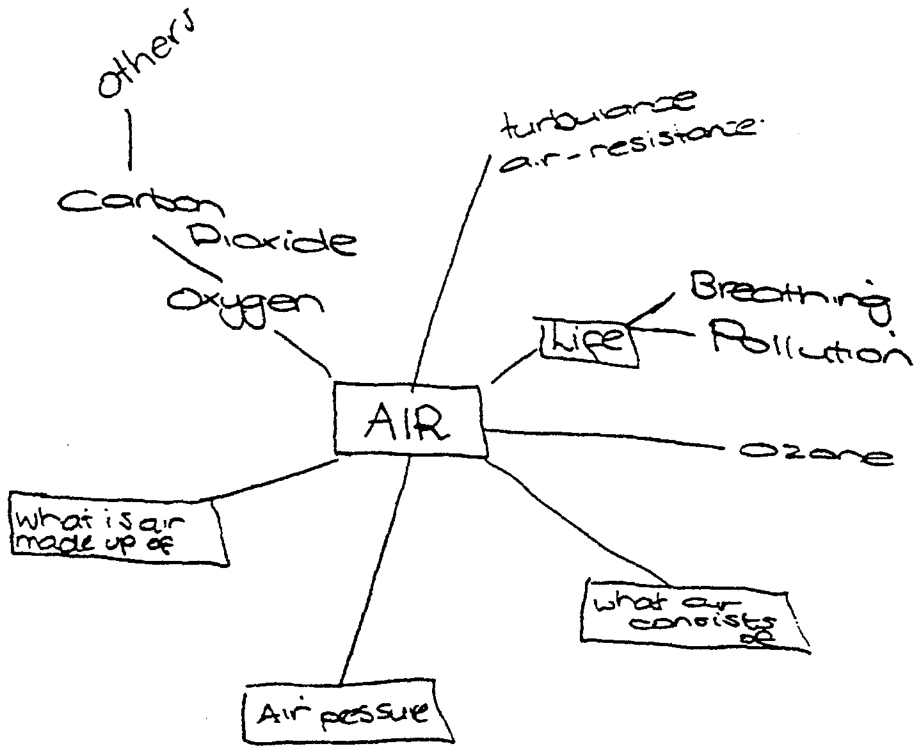

Figure 3. Julie's initial concept map

To develop an understanding of the science concepts, the preservice teachers trialed the practical activities and completed individual research on the topic. Discussion of ideas within the working groups was beneficial in clarifying ideas, and for the sharing of knowledge: "Explaining information to others helps you to understand the concepts better. In groups it tends to be easier to stay on track, also if you don't understand how to experiment the other members of the group can assist you" (Jane, Journal - 1/9).

In some situations, an individual's views were challenged during the practical activities and they began to question their understanding of the science ideas. For example, while working with magnets, Craig was trying to explain why the North of a freely suspended magnet points to the North Magnetic Pole. He was particularly concerned with the need to resolve this idea: a contradiction for Craig in terms of the science idea that of like poles repel (RP, Journal - 5). He eventually resolved this contradiction through some additional individual research on this aspect. While working through these questions relating to his understanding, Craig was beginning to consider how the ideas would be discussed with primary students: "How do I explain this to students?" (RP, Journal - 5). Although Craig did not resolve this aspect at this point in time, he was beginning to consider the learner in the process of transforming ideas for the classroom.

Each of these examples was typical of the methods used to develop preservice teachers' understanding of the science content knowledge by the class group. In developing this knowledge, practical activities, individual research and group discussion were used to build on their existing knowledge of the topic.

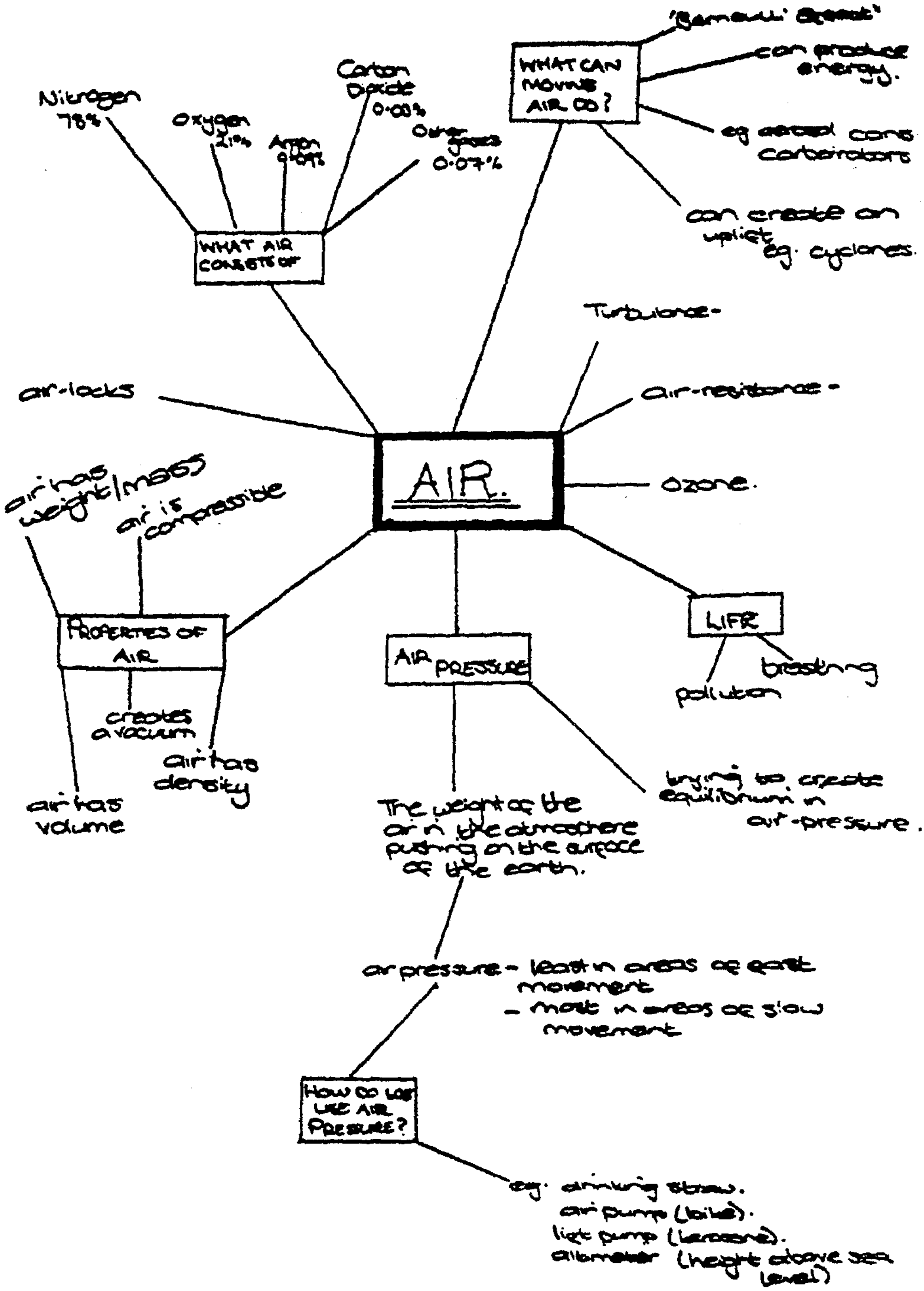

Figure 4. Julie's final concept map

Knowledge of Curriculum

In addition to an understanding of the science content, the preservice teachers also recognised the need to have an understanding of the relevant curriculum materials associated with the science concepts. These curriculum materials were considered a useful resource in clarifying ideas and "were also useful guides in providing a model to base the presentation of these [science] ideas" (Jane, Journal - 1/14). As they were required to teach part of the unit to another person, the curriculum materials now had greater significance in their learning:

> Curriculum materials were vital to my presentation and explanations. The learner has to be able to fully understand a topic using resources and participating in activities. Theories or explanations are insufficient. Curriculum materials should be a major part of science and I have tried to use them as much as possible during my presentation/explanation of ideas. (Craig, Journal - 1/14)

Individuals were beginning to evaluate critically the effectiveness of curriculum activities and resources. Sally, for example, suggested an alternative for the activity using two balanced and inflated balloons (one which is later burst) to illustrate the idea that air has mass. Sally's comment on this activity was:

> Air has mass. A difficult concept to deliver, because children can't feel the weight of air and because it is so minute is difficult to measure. Rather than the activity we used I would suggest the following alternative. Attach two uninflated balloons to a metre rule. Suspend this so it is balanced. Inflate one balloon and notice that the balance is disturbed. This balloon is obviously heavier and the only thing that has been added is the air in the balloon. Alternatively, if an electronic balance is available an uninflated balloon can be weighed, inflated, reweighed, and the results compared to prove that air does weigh something. (Sally, Journal - 1/13)

Although the preservice teachers were reviewing and evaluating the curriculum activities associated with the two topics, they did not have to research and identify suitable curriculum materials. They believed the curriculum ideas supplied in the handout were relevant and appropriate when teaching a peer (RP, Journal - 7).

Transformation

During this stage, the preservice teachers considered the teaching sequence, the science content and curriculum knowledge, the prior knowledge of the learner, and the explanations they would use for the activities to be discussed. Some of these ideas are illustrated in Julie's discussion relating to this phase:

> During the planning stage, I learnt that there is a lot of information that needs to be passed on to the learner. You cannot be choosy about the information that you give, it is whatever needs to be learnt. I also learnt that you need to sequence ideas that you are going to teach. You need to plan the right demonstrations to go with your explanations and you need to have other explanations ready other than the scientific explanations. It is important that you choose the right information for the learner to learn. (Julie, Journal - 1/17)

The need to have some background knowledge of the peer whom each person was to teach was identified through a discussion during one of the weekly classes. From this discussion, it was decided by the class group to collect information, via a survey questionnaire, from each member of the class on their understanding of the topic they were to be taught. These questionnaire responses were evaluated to establish the range of understanding of all members in the class group, and this information provided a basis for the preparation for the peer teaching (RP, Journal - 4). A review of their journals indicated that 19 of the 21 class members recognised the importance of having some understanding of the prior knowledge of their peers in deciding on a starting point for their teaching. The following comment typifies their views on the value of assessing a student's prior knowledge of the science concepts:

> What the person already knew about the topic was very important information. It allowed us to view *what* [her emphasis] the person knew, how much they knew and it also allowed us to determine in which areas, if any, the learners were misinformed and in which area we didn't have to go into great detail because they already had some prior knowledge. (Julie, Journal - 1/15)

The peer teaching component of the problem-based unit was instrumental in focusing preservice teachers on the need to consider the prior knowledge of the learners when planning a teaching activity. In this unit, their exploration of another person's understanding of the topic was through a questionnaire. Although other approaches could have been used to explore the students' prior knowledge of the topic, the important issue was that they recognised the need to consider the prior understanding of their peers as part of the teaching process.

The ability to explain science concepts had been identified through the initial interviews as an area of concern for the preservice teachers. During the transformation phase, 11 of the 21 members of the class did consider the explanations they would use when teaching their topic to their peer. They relied on the use of the practical activities, diagrams explaining ideas, or examples of relevant situations where the concept may apply. The remaining 10 members did not consider the possible explanations that they may be appropriate when explaining an idea to their peer.

When deciding on the appropriate sequence, 17 of the preservice teachers used the prior knowledge that each person had on the topic when assessing a starting point for their lessons. The lesson sequence usually followed the "simple to complex" or "familiar to unfamiliar" description of concepts:

> We looked at the prior knowledge exhibited in the survey [questionnaire] the other people filled in and decided to start with the familiar - air is our atmosphere - and then move into newer areas. The sequencing attempts to follow a logical path, e.g., atmosphere is finite, it then seems logical to discuss air taking up space. Then if the space is altered we come to elasticity and compression. Mass was last because it is perhaps the hardest concept to explain. (Sally, Journal - 1/12)

As they were teaching in a one-to-one situation for this activity, they did not place great emphasis on the teaching strategy to be used. Preservice teachers either allowed their colleague to explore the ideas first and then discussed the ideas, or alternatively they provided their colleagues with some information and then allowed the person to do the activities. One member (Robert) of the class did describe his reason for the teaching method selected. He modelled his teaching on the approach used by his secondary science teacher, as he believed this was a most effective approach when he was learning science in secondary school:

> What did help me was the way my science teacher at high school presented lessons. I started off with a short introduction. My science teacher used to tell us what to look for in the experiment. This is what I would do and then ask my peer what happened, then I would explain the concept. (Robert, Journal - 1/14)

Although Robert was using a teaching model based on his observations of his secondary science teacher that may have been inappropriate for primary science teaching, the critical issue was that he was at least making decisions about a teaching strategy. If, after trialing this strategy, Robert was not satisfied with the approach he could then modify his teaching approach to suit primary students.

Instruction

Two main instructional approaches were used during this teaching phase. Preservice teachers either used a discovery approach or more traditionally introduced theory followed by a practical approach. Those using the discovery approach allowed their peer to explore the activity first, and then followed with a discussion of the science idea:

> I moved onto the activities pretty much before the explanation...do the activity, things like mass, volume, elasticity - the properties of air - before we came to the explanation, go through "What do you think happened?" And if they don't know, then I will explain, well this is what happened - can you think is there anywhere else that you can apply this...So it was pretty much a self-discovery activity. (Sally, Interview - 1.2, pp. 3-4)

Alternatively, preservice teachers using a 'theory first' approach provided some information on the concept, and then reinforced the science ideas through a practical activity and further discussion. The purpose of the peer teaching phase was to allow each person to trial a teaching approach and then review their teaching in light of this experience. Therefore, the teaching strategy used was not of most importance in the process; rather how the strategy was reviewed in the subsequent stages of the pedagogical reasoning process was more important.

Evaluation, Reflection and New Comprehension

These three stages have been discussed together because of the inter-relationship between them. For example, preservice teachers' views on evaluation can influence their reflection, and consequently their new comprehension of the topic. In their teaching role, they were able to evaluate their own teaching performance, and evaluate the learning of their peers. Their comments varied from general evaluative comments, through to specific comments focussing on particular aspects of their teaching or planning. A typical general evaluation comment was:

> I thought virtually all aspects of this lesson went well. The explanations I gave seemed to satisfy Julie, and from what I could gather she understood to a reasonable degree what I was trying to explain. After a bit of discussion, Julie knew how electromagnets worked, although she was still unsure of why it worked the way it did. (Karen, Journal - 1/20)

Specific evaluation comments focussed on the need for improved explanations of science ideas, better sequencing of ideas, having more activities and demonstrations to support science concept development, and having a clear understanding of the science concepts themselves prior to teaching.

One benefit of the peer teaching activity was the opportunity to explain ideas to another person. Ten preservice teachers found explaining one or more ideas to be difficult:

> The explanation and discussion did not go as well as expected. I feel the learner could not contribute effectively to discussion as some confusion was evident after viewing the activities.

> Explaining the ideas was difficult and so was encouraging a clear understanding of the concept. Further clarification was needed than what I was able to provide. (Jane, Journal - 1/20)

Four of these preservice teachers attributed their inability to explain the idea because of their understanding of the science content knowledge:

> When I went over the notes I understood what I was going to teach, but I found it a lot more difficult to explain to others. In my mind it seemed clear, but when I verbalised it, I could tell myself that it wasn't all that clear. The more I tried to clarify points the more difficult it became. (Tanya, Journal - 1/13)

In the role of learners in these sessions, the inadequacy of the explanations of ideas was recognised:

> Explanations were very clear except where the teacher felt unsure of the topic, in which case she had a tendency to skip over them and say "Oh you don't really need to know that" or "no-one else really knows it". (Tanya, Journal - 1/26)

Four preservice teachers were not confident with the explanations they had received for the topic. The other 17 preservice teachers believed most, if not all ideas, were explained adequately. Therefore, one of the benefits of this aspect of the problem-based learning activity was that it enabled preservice teachers, in the position of either the teacher or the learner, to consider the quality of the explanations of the science ideas for the topic.

The preservice teachers reflected on a variety of issues in relation to their own teaching and planning of lessons. The comments made focussed on the need to improve their personal understanding of the science content, being better prepared when teaching, having more activities and student discussion during lessons, improving their explanations of ideas, and establishing ways of evaluating what the learner has understood through the lesson. One of the more detailed descriptions illustrating new comprehension of the teaching process was:

> Identifying the students' prior knowledge is important to know - what you need to build on. The importance of planning, sequencing and linking ideas. Using appropriate activities and having available resources. Linking activities with explanations. Discussion and clarification of students' ideas at the completion of the lesson. Explanations need to be clear and understood by the learner. Language needs to be considered. Linking what is learnt with everyday life. Using alternative explanations. (Michelle, Journal - 1/21)

The preservice teachers as learners benefited from being able to review what their peer had taught them, the approaches they used when teaching, and how effective these approaches were in teaching the topic. In this learning role, the preservice teachers were evaluating the teachers' ability to explain concepts, the teaching sequence used, and the effectiveness of the practical activities in improving their understanding of a particular science concept. For example, Mark was critical of the level of evaluation of his learning: "I also think that the handout sheet that I received could have included some simple questions on each concept, just to test to see if I did really understand what was happening in each activity" (Mark, Journal - 1/27). For Sally, who was already familiar with the concepts and possible activities in the topic, the benefit in the peer teaching was "to see some-one else's approach to teaching" and "to evaluate what I would use or do differently in the primary situation" (Sally, Journal - 1/27). These peer teaching sessions enabled Sally and Mark to reflect critically on the teaching practices of another person and in doing so increased their understanding of the role of the teacher when teaching science.

Conclusions

It was evident from the interviews with the seven preservice teachers at the beginning of the unit that they only discussed the comprehension and transformation stages of the pedagogical reasoning process, and indicated a teacher-centred approach in discussing the planning of lessons. When discussing issues in relation to their teaching ability in science, they recognised the need to develop their science content knowledge, curriculum knowledge, knowledge of learners and the ability to transform ideas to suit a particular grade. These findings on preservice teachers' pedagogical reasoning skills are similar to those from a pilot study by Peterson and Treagust (1992).

After completing the problem-based unit, all the preservice teachers in this case-study had been more likely to use a pedagogical reasoning framework based on the six stages, and had integrated their knowledge of science content, curriculum and learners in the process of preparing and teaching a unit of work. One of the significant aspects of this unit was the recognition by the group of exploring the prior knowledge of the learner when preparing to teach.

The comments made by Craig and Jane, which include the ideas discussed by the majority of preservice teachers, highlight the benefits of this pedagogical reasoning unit:

> I feel this process is very beneficial. The main aspect is the fact that you really have to put yourself in the position of the other person. This means you not only have to know your topic but formulate methods and ideas to be able to teach it to them. This was most beneficial in that I learnt the topic much more thoroughly than I normally would have. In summary, I feel it is a much more thorough and practical way as learning in that you are using both theory and practical ideas and you have to use thinking skills much more than regular class lessons. This process forces you to be an active participant instead of simply remembering knowledge. (Craig, Journal - 1/21)

> The process that I went through, I believe was beneficial in developing my understanding of both the concepts being taught and learnt as well as the experience of actually teaching the concepts. This side was useful and made me aware of the needs for clear explanations, demonstrations, activities etc. in science lessons. (Jane, Journal - 1/21)

The use of a problem-based approach in which the problem was placed in a context enabled the preservice teachers to begin exploring their pedagogical reasoning ability, and to apply their knowledge of science, curriculum and learners to the situation. The group interactions combined with student-centred learning were particularly useful in developing all stages of reasoning. Through the process, individual preservice teachers focussed on issues which were relevant to their own learning needs, and their developing understanding of the teaching process.

The use of guiding questions on pedagogical reasoning enabled the small groups to have much more control over their learning. However, some preservice teachers were critical of the journal questions, and the need to complete these questions each week. The style of questions used in the journal to guide the process in a problem-based learning context needs further review.

This study has demonstrated that it is possible for preservice teachers to acquire, both individually and through the small group process, the necessary science content knowledge, curriculum knowledge and knowledge of learners when planning to teach a science topic. Furthermore, the pedagogical reasoning process modelled in this PBL program enabled the preservice teachers to address issues that were relevant to their teaching of primary science, and to build upon their knowledge and understanding of this teaching process. The PBL model developed in this study, which focuses on improving preservice teachers' ability to design, teach and evaluate their science teaching, provides a possible approach to the delivery of primary science education units. The potential exists to design problem scenarios addressing a range of issues (e.g., gender inclusive teaching, linking science and technology) in primary science teaching.

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