Abstract
This paper describes how pre-service teachers in one Higher Education Institution in England are prepared for the task of teaching primary science. The course is outlined and provides the context for the findings. The underpinning theory that furnishes the course with its rationale is discussed. Quantitative and qualitative data were collected and analysed and offer an insight into the effectiveness of the course.

Introduction
The debate about education and training has been an extended one (Bernstein 1996, Crook 2002, Pring 2004). The development of assessment based on a range of competencies within teacher education has made this debate relevant and pertinent to teacher educators worldwide. Within science education, these arguments are complicated by differing philosophical views about the nature of science and consequently how science should be learned and taught. The interpretation of these views and the stance taken by course providers influence the nature and type of course that is provided for pre-service teachers and subsequently affect their ideas and beliefs about science and how it should be taught (Kagan 1992, Fang 1996).

This paper sets out to describe and explain how one higher education institution in England has set out its philosophy about primary teacher education in science and developed a course which is thought (by the course tutors) to go beyond the competency issue by developing newly qualified teachers who are reflective, self critical and analytical (Long and Stuart 2004).

Preparing to teach primary science
Training primary teachers who are confident and competent to teach science has been a matter of concern for several decades (DES 1978, Black 1983, Ofsted1999,
Mulholland and Wallace 2003, Abd-El-Khalick and Akerson 2004). In England, the matter of teachers’ expertise became a more urgent issue with the introduction of the National Curriculum, which saw science take its rightful place as a core curriculum subject alongside English and mathematics (DES 1989). Throughout the 1980s and early 1990s several centrally funded initiatives were undertaken to address the lack of subject knowledge and confidence to teach science effectively and to redress the balance of earlier discovery based learning and ‘hands-on’ approaches (Kinder and Harland 1991). However addressing teachers’ subject knowledge was not as successful as initially had been hoped (Kruger et al. 1990). One approach that can affect the quality of science teaching within the primary classroom is to ensure that those in pre-service training are well qualified to teach science effectively before they enter the profession. Effective teaching and learning in the classroom is described by Shulman (1986) as ‘curricular expertise’ and includes subject matter content knowledge, pedagogical content knowledge and curriculum knowledge; he goes on to suggest that training has an impact upon the acquisition of teacher knowledge. Recognition that subject knowledge, subject-related pedagogy and knowledge of the curriculum are important in teaching science effectively and with enthusiasm is well documented (e.g. Kruger and Summers 1989, Russell et al. 1992, Summers et al. 2001). This provides a real challenge for many students. Firstly, like other pre-service teachers many do not have a scientific background and although they will all have had some formal science education at school this has often left them with negative attitudes towards science and science teaching (Parker and Spinks 1997, Tosun 2000, Mulholland and Wallace 2003, Palmer 2004). Secondly in training to teach within the primary phase these students have to cover all areas of the curriculum, increasing the demand on their capacity to absorb subject expertise.
The context for teacher training in England

There are a variety of primary teacher training courses in England, ranging from four year undergraduate courses to a one year postgraduate certificate in education. Like many other countries primary teacher training covers the whole curriculum and takes place in two separate situations; the higher education institution and schools (Asoko 2000).

The requirements in England to achieve Qualified Teacher Status (QTS) have been through several revisions in the last ten years. The version prior to current requirements placed a high emphasis on learning subject knowledge and a national curriculum for Initial Teacher Training in English, mathematics, science and ICT was produced. The science curriculum detailed the subject knowledge as well as science specific pedagogical knowledge that trainees were expected to know by the end of their training (DfEE 1998). As a result teacher training became highly prescribed. However recent changes (DfES /TTA 2002) to the requirements have removed this level of detail and simply state that; trainees must demonstrate ‘a secure knowledge and understanding of the subject(s) they are trained to teach’, whilst emphasising the professionalism, generic teaching skills and curricular expertise needed to be a successful trainee teacher. The view taken here is that all of these elements are crucially important. Teachers need to have appropriate science subject and subject-related pedagogical knowledge and understanding as well as a good knowledge of the curriculum. They must also be highly professional in their approach and attitude to their work and be accomplished in generic teaching skills.

The primary science course

The course described here takes place over 38 weeks of an academic year and forms one element of a Postgraduate Certificate in Education (P.G.C.E.) which has to comply with the standards set out in Qualifying to Teach (DfES/TTA 2002). The P.G.C.E. has two major
components, a university based element in which students are taught science as well as other curriculum subjects and educational studies and a school based element where the students practice teaching and develop their pedagogical knowledge and skills.

Course aims and theoretical framework

The overall aims of the science course are to train teachers who are confident and competent practitioners of primary science. Shulman’s views about what a teacher should know in order to practice effectively are taken into account. The development of subject knowledge in which the content and processes of science are simultaneously developed is a major aspect of the course. The importance of pedagogical knowledge is equally apparent throughout the course and is developed together with curricular knowledge and expertise. All of these aspects of a teacher’s knowledge are attended to within the university and school based elements of the course. Furthermore, as Pring (2004) suggests, ‘a well trained teacher is useful but an educated one is better’ p. 113, and this is the view taken within this course. Students are expected to be capable practitioners but the skills they have learned and can execute are intended to be informed by a wider intellectual grasp of science and the nature of learning. The approach taken to achieve these aims is based within a constructivist view of learning and students are expected to apply their meta-cognitive knowledge, skills and experience in relation to science as they reflect upon their own learning of science and science teaching.

The constructivist view embraces a process of learning for the students themselves and a theory of learning science. A constructivist approach to knowledge is considered to be a process of ‘meaning making’ and begins with the learner’s perspective (Tobin et al., 1994) is supported within the course. The students who come to the course have very different educational backgrounds and this must be taken into account so that each individual can construct their own meaning about science and develop their own schemata. To this end, the
students use baseline data to develop an individual learning plan, which is seen as a basis from which developmental changes are made rather than a deficit in need of remedy (Mulholland and Wallace 2003). However, constructing one’s own ideas can also be socially driven (Bandura 1986) and within the course individuals are expected not only to learn via the various experiences for themselves but within different groups and social contexts. This learning experience provides a model which the student is able to transfer to children’s learning when they go into school.

The course that is described here, in keeping with many other teacher education courses, considers that teaching can be made more effective by thinking about and analysing one’s knowledge, skills and attitudes (Loughran 2002, Ryan 2003, Parker 2004, Abd-El-Khalick and Akerson 2004). Schon’s (1987) notion of a reflective practitioner; one who reflects ‘on’ and ‘in’ practice is inherent in the course. The students are expected to constantly reflect upon their own learning throughout the course and to develop a critical stance in thinking about their own knowledge and understanding. It is through this process of critical reflection that cognitive change can be effected (Yost et al., 2000). In order to develop and make progress in learning, reflection must be about what is known as well as what is not and this involves thinking about the learning process itself. This meta cognitive approach offers students an insight into the learning experiences of the pupils they will teach (Parker 2004).

The students
Recruits for the Primary P.G.C.E. (Post Graduate Certificate in Education) are graduates from a range of disciplines and many who embark on the course do not have a scientific background. However they are well qualified in their general education and the majority have good class honours degrees. The 126 students discussed in this study are from a cohort of one
year of the P.G.C.E. 7 students had a science degree or science related degree such as Sports Science or Health Studies and 12 of the cohort were male.

The course outline

The duration of the course is 38 weeks of which 18 weeks are spent in school. During the time they spend in the university the students are taught science by specialist science tutors for 15, three-hour sessions. The trainees are expected to follow up each session with reading and directed tasks. The science sessions are designed to cover subject knowledge, subject-related pedagogy, knowledge of the school curriculum and professional practice within a variety of teaching and learning approaches. Typically, these include mini lectures, practical tasks and activities, micro-teaching, presentations, question and answer sessions, seminar discussion and plenaries. The school based element of the course takes the form of three main block placements in different schools and the trainees are expected to teach science as well as all the other curriculum subjects to the class of children they are placed with. At the end of the course the students’ level of competence in science is graded in the following areas, knowledge and understanding, planning expectations and targets, monitoring and assessment, teaching and class management.

The science course and the process of learning to teach primary science

Acquiring good subject knowledge and understanding is an important aspect of the course. It is regarded as including content knowledge and syntactical knowledge (Heywod 2004). At the beginning of the course students undertake a written test and complete an audit covering these aspects of subject knowledge. Both the audit and test subdivide various aspects of subject knowledge into areas that closely align to the science school curriculum in England (DfES 1998). The audit and test includes:

- Scientific enquiry – ways, methods, communication, health and safety and the nature of science;
• Life processes and living things;
• Materials and their properties;
• Physical processes.

These assessment features provide the student with baseline information about their own subject knowledge of science and their understanding of science which is used to develop targets for further progress. This process is repeated at the end of the course when direct comparisons of progress can be made. The taught science course covers all major areas that form part of the school science curriculum. Expectations of students are, that they will achieve good subject knowledge and understanding in all of these areas of science and the standard is set to be at a level comparable with the General Certificate of School Education (G.C.S.E.), grade A.

The associated pedagogy or pedagogical content knowledge related to teaching science and knowledge and understanding of the school curriculum are also regarded as highly important and expectations that students will consolidate their learning in these areas are also high. Students are required to audit their confidence in their ability to apply their scientific knowledge and skills to teaching the science curriculum at the beginning and end of the course. Developing a repertoire of effective pedagogical approaches is complex and continues throughout one’s teaching career. However the course aims to do more than offer tips for teachers in order to ‘get started’ and provides information about a wide range of pedagogical approaches to science, which tutors model during their teaching. Students also have opportunities to practice these approaches and refine their teaching skills in the safe confines of the university classroom with their peers before venturing out into school to work with children. In a similar manner, students are offered ample opportunity to investigate and become familiar with the curriculum they are expected to teach. Students are required to consider how they would teach science appropriately and with interest, whilst taking into
account what children might already know about the topic and what common misunderstandings children might have.

In order to achieve these goals the taught element of the course employs a variety of teaching and learning activities such as interactive lectures and seminars, modelling, practical activities, demonstration, micro-teaching, self directed study, reading and tests. Furthermore students are introduced to key research findings, in particular, to children’s understanding of science and scientific phenomena. School placements offer students opportunities to put into practice what they have learnt at university and to develop and hone all aspects of ‘teacher knowledge’.

However, consolidation of learning requires a process of critical reflection and subsequent assimilation (Yost et al. 2000). The notion of reflection is viewed within the course as an active process in which students are expected to clarify positive outcomes as well as points for future improvement, which they articulate as targets to achieve and thus make efforts to assimilate into their cognitive structures. As part of formalising this process of reflection, construction of personal knowledge and thinking meta-cognitively students are required to maintain records of their learning. This is achieved in several ways. The completion of an audit, test and participation record at several points during the year, evaluating teaching and learning routinely after each science lesson they have taught. The production and maintenance of a science file which becomes a personal working document for each student and discussion of student classroom performance with mentors and tutors. Discussions with peers provide a more informal context in which to reflect.

Whilst the cognitive aspects of students’ competence in science are highly important, affective dimensions are also crucial in becoming a successful teacher of science. Teachers’ views and attitudes towards science can materially alter not only how science is taught within their classroom but whether it is taught at all (Harlen and Holroyd 1997, Long and Stuart
The opportunity to reflect formally and informally upon experiences within the university based and school based elements of the course offers students the opportunity to develop their own views and attitudes towards science and provide a personal rationale of how they want to teach it.

Course outcomes

Qualitative and quantitative data of course outcomes were gathered on several occasions during one year of the Postgraduate Certificate in Education. The data were used to provide an insight into the extent to which the science course meets the needs of the trainees as well as the quality of science teaching achieved by trainees at exit point on the course. The following items formed the data sources

The audit and test record

A random opportunist sample (25% of the cohort) of audit and test records were used to provide information about the students’ subject knowledge and understanding, teaching confidence and their interest in science at the beginning and end of the course.

Evaluations

110 course evaluations were completed and data provided information on how well prepared students considered they were for teaching and what had been useful and relevant in learning to become a teacher.

Questionnaires

A semi-structured questionnaire to discover the students’ views about science and teaching science and what had changed as a result of completing the course was given out. This was a voluntary exercise and 60 were returned completed, representing a 47.6 % return rate.
Final placement grades

This assessment is completed by university tutors in conjunction with the class teachers that the student has been working with. The 119 completed assessments provide information about the grades achieved at the end of the students’ final teaching placement. A range of teaching skills and knowledge are assessed and provide students with further evidence of their ability to teach science effectively. The areas assessed are directly linked to the standards for qualified teacher status in England (DfES/TTA 2002), which are:

- Professional values and practice
- Knowledge and understanding
- Planning
- Monitoring and assessment
- Teaching

The areas assessed an inverse scale and are based upon the following criteria:

1 = very good, meets all the requirements for any given area and excels in some
2= good, meets all the requirements for any given area
3= adequate, meets most of the requirements for any given area but shows significant weaknesses in some
4= poor, meets some requirements for any given area but shows significant weaknesses in most

Findings

The findings provide an indication of the level of progress students have made in all aspects of the science course.

Subject knowledge and understanding
The audit

Figures 1, 2, 3 and 4 show the grades students gave themselves in September at the beginning of the course and in June at the end of the course. The grades are on a reverse scale and the key is explained below:

1 = subject knowledge exceeds the professional requirements of the professional
2 = meets the requirements
3 = subject knowledge is at best only ‘adequate’
4 = subject knowledge, understanding and skills is unsatisfactory

All areas audited indicate that progress is substantial. No students consider themselves as unsatisfactory or adequate at the end of the course. The shift to meeting the requirements or exceeding them at the end of the course represents 78% of the sample for Scientific enquiry, 47% of the sample for Life and living processes, 69% of the sample for Materials and their properties and 80% of the sample for Physical processes.

Figure 1: Audit of subject knowledge

![scientific enquiry](image1)

![Life processes and living things](image2)

![Materials and their properties](image3)

![Physical processes](image4)
The test

The results of the test scores at the beginning and the end of the taught course also indicate progression in subject knowledge. Comparison of total scores for all four elements of the tests, described earlier, can be seen in Figure 2. The pass mark is 75% in each element of both tests. 100% of the sample passed all elements of the test after the course compared to 1% for Scientific enquiry, 27.5% for Life and living processes, 37.5% for Materials and their properties and 0.3% for Physical processes in the initial test at the beginning of the course. Every student has improved their scores and for some the improvement is very great indeed. The improvement in knowledge and understanding of physical processes for almost all students is worthy of note.

**Figure 2: Total test scores**

![Figure 2: Total test scores](image)

End of placement grades

The end of school placement grades for knowledge and understanding, which includes knowledge and understanding of the curriculum are shown in figure 3. A mean grade score 1.68 was achieved by the student cohort and 37.8% of the sample gained grade 1. These grades indicate that students demonstrate high levels of subject and curriculum knowledge and understanding whilst teaching children.
The Questionnaire

57% of responses indicated that one of the differences that the course had made was an increased level of subject knowledge and understanding and the confidence that this offers. The comments below illustrate this;

‘I now have the necessary knowledge and understanding to teach science competently and successfully’

‘I’d done no science since school; (I) was quite scared by it and my lack of subject knowledge and I now feel much more confident in subject knowledge’

Some comments indicate that students have reflected on their learning and the process of their learning and realise that this learning will continue;

‘I feel more confident in my abilities and I believe that I have learnt and can learn the required knowledge to successfully teach’

‘I have boosted my science knowledge and understanding a great deal and thanks to the course now know where to look should I need support and ideas’

The course evaluation

Increasing subject knowledge and understanding featured as one of the aspects of the course that students considered to be useful and relevant for them. 20% mentioned subject knowledge generally. Others, 67%, specified particular areas of subject knowledge in which they had learned a great deal; environmental education and astronomy were the two areas
mentioned most frequently, with 35% and 33% of the comments respectively. Additional comments about subject knowledge indicate that for students this is a very important aspect of the course.

‘The subject knowledge that has been provided has been very useful and interesting’

‘I have learned so much!’

‘I have learned loads and enjoyed doing so’

Teaching

The Audit

Figure 4 shows the change in students’ views about their ability to teach science as it relates to the school curriculum with confidence and competence. The grades are on an inverse scale and refer to

1 = very good, might even feel happy to support colleagues

2 = good, further professional development required in some aspects

3 = adequate, further professional development required in most aspects

4= poor, Help! further professional development essential in all areas

The results show that students consider that their ability to teach has improved greatly as a result of the course. No student considered themselves as poor or adequate by the end of the course in any of the science curriculum areas audited. The shift from poor or adequate to good or very good represent 50% of the sample for Scientific enquiry, 65% for Life processes and living things, 81% for Materials and their properties and 100% for Physical processes. Progress is considerable in all areas and very high levels of progress are apparent with materials and their properties and physical processes.
Comments about ability to teach science at the beginning of the course indicate concerns about the lack of subject and pedagogical knowledge,

‘. unsure of the level of my ability and retention of knowledge as it was so long ago since I used the information’

‘I’m unsure of the level needed to teach and of my own subject knowledge’

At the end of the course, comments focus on an increased confidence, enthusiasm and interest in teaching science. All aspects of the course seem to be valued in helping students achieve this goal, indicating an ability to view their learning holistically.

‘university based session, directed activities, self study and teaching practice have altogether meant I feel very confident in my ability to plan, research and teach all areas of science’

In addition there is recognition of their own learning experiences and reflection on how these can be employed to teach.
‘I have thoroughly enjoyed teaching science and I’ve realised and learned that you really can make lessons very interactive which all children love’

‘much more up to date subject knowledge and understanding of the subject and how to engage young children’

Whilst this student appears to have an overview of the whole curriculum and indicates an understanding of the breadth of science and how science can benefit children’s learning in different contexts

‘My confidence and enthusiasm have both increased, I feel more confident to teach science a part of the curriculum rather than as a subject in its own right – I am excited about the teaching and learning prospect’

Placement grades

The end of placement grades given to students by their class teachers and mentors are shown in Figure 5. The students have a mean grade score of 1.72. The grades indicate that the students have reached a high level of competence in teaching science and 36% students gained a full set of grade 1’s within this part of their assessment.

**Figure 5: End of placement grades for teaching**
Questionnaire

53% of the comments indicate that the students consider their ability to teach science has altered as a result of the course. They also show that students have reflected upon their learning and have made great strides towards developing themselves into effective primary science teachers.

The students’ lack of confidence and their own, often negative, school experience are prevalent in their reflections about how they would have taught science at the beginning of the course,

‘didn’t really enjoy science at school, and didn’t relish the idea of teaching it’

‘like a secondary(school) lab!’

‘I hated science at school… had no idea how to teach it’

‘disliked science… not sure how to teach it… had particular difficulties with physics’

Others indicate that at this stage they would have employed didactic methods and relied on text books and pre-prepared worksheet even though they realise that this is not an ideal approach for primary science,

‘I think I would have taught science using books and made the children do lots of writing’

‘Very much sit down and learn, boring and stuffy, pointless activities and jargon!’

‘I wouldn’t have known where to start before the course, I would probably have fallen for the worksheet and reading trap’

‘Worksheet based… boring!’

Interestingly some students who felt they had sufficient subject knowledge to teach at primary level at the beginning of the course realised that their pedagogical approach would be
inappropriate but that until they had been through the course they didn’t know how to teach appropriately,

‘I have good basic understanding of the concepts and would have felt confident within the subject area teaching; however I would not come up with the ideas/ways to teach that’

I would have taught with enthusiasm ...but it would probably have been over technical and not as appropriate as it should have been for primary children’

At the end of the course the students respond with a variety of ways in which they could teach science. They are aware of a range of approaches as well as resources that they can use. They recognise the need to engage the children’s interest and how to help children to construct reliable knowledge,

‘I have developed skills of engaging the children and letting them discover for themselves, not just feeding them curriculum knowledge’

‘I enjoy teaching science and have now made my teaching as interactive as possible in order to stimulate the children’s thinking, especially if they have little personal experience’

Many students reflect upon their increased confidence and enthusiasm to teach science and this seems to stem from their increased subject and pedagogical knowledge. They not only feel empowered to teach science but are eager to do so.

‘didn’t ‘get’ physics (at school) l but I’m looking forward to teaching it now!’

‘the course has taught me a great deal about the subject, now confident in teaching it in an exciting way’

‘am now aware of how fun science can be, really enthusiastic about it, by far my favourite subject to teach’

For some students their enthusiasm about teaching science has led them to reflect beyond the immediate qualification and consider their future career development.

‘I want to become a science coordinator!!!’

‘would really enjoy being a science specialist now!’
End of course evaluations

When asked how they would rate the science course over the whole year in preparing them for teaching; the students gave an overall grade of 4.7 out of a total of 5, where 1 = poor and 5 = excellent. 74.5% mention directly that they consider themselves more appropriately equipped to teach science.

The students’ comments indicate that they felt the taught course prepared them well for teaching and that their confidence and enthusiasm to teach well had been increased,

‘my confidence has been boosted both in subject knowledge and teaching ability’

‘the course has given me the enthusiasm, motivation, resources and knowledge to go into schools and teach science confidently’

‘I’m going to give it my best shot to excite the world with regards to science!!’

Curriculum Knowledge

Placement grades

There are two areas graded for curriculum knowledge at the end of school placement. The first is included in subject knowledge (of the curriculum) and has been discussed earlier. The other grade concerns the application of that knowledge in planning appropriately for the children that the students are teaching. The mean grade score for this assessment was 1.72, with 36% of the sample obtain grade 1. Figure 6 shows the results for the sample, 92.4% of the students are assessed as at least good within this aspect of their teaching placement.
Figure 6: School placement grades for planning

Questionnaire

15% of the comments referred to a more informed view of the curriculum and the statements indicate that this is regarded as an important aspect of being able to teach effectively.

‘I am now able to teach science and enjoy it; I know the curriculum requirements for science’

‘I know what aspects of science need to be taught and am aware of the need for interactive teaching’

Students also indicate an awareness of the need to make their teaching relevant and appropriate for children,

‘I know where to pitch my lessons and I also elicit existing knowledge from the children at the start of the lesson’

‘I now teach science which is pitched at an appropriate level for children throughout the key stages’

End of course evaluations

29% of the sample state that one of the most useful aspects of the course was enabling students to be more aware of curriculum requirements. Students have reflected upon their increased knowledge and understanding of the curriculum by indicating their awareness of the relevance of the course to the school curriculum.
‘relevant to the classroom and teaching at key stage 1 and 2’

‘pitching it at the right level for teaching primary’

Attitude towards science

One of the main findings that prevail in all of the data gathered is the change in attitude towards science and teaching science. Students’ interest in and confidence about science has increased as a result of the course. The change in student views is quite remarkable and for some students it is a revelation to them that science, especially physics is not necessarily difficult or boring.

The Audit

Figure 7 shows the change in interest in science between the beginning and end of the course. The graph indicates quite high levels of interest at the beginning of the course the qualifying comments reveal that the students have reservations about science because they think it is dull, difficult or obscure. Their innate interest seems to be affected by attitudes that have arisen from their experiences, especially secondary school physics, of science and their teachers.

**Figure 7: Audit of interest in science**
‘I didn’t enjoy physics… boring teacher!’

‘I love biology… had a good teacher, didn’t enjoy chemistry the teacher was boring’

‘I found it difficult, especially physics and the teacher wasn’t good’

However by the end of the course much of this has changed and the students’ reflections about their learning seem to indicate that they have become science ‘philes’ rather than science ‘phobes’. Their attitude towards teaching science has also changed and many comments show an awareness of their own growing ‘teacher knowledge’.

‘I have really enjoyed this course it has increased my fascination in this subject. I have also enjoyed teaching young children and developing their knowledge of the world around them’

‘I have developed a real enjoyment and enthusiasm for teaching science in school and have developed a range of teaching methods for this subject to try and engage all learners’

‘I have thoroughly enjoyed teaching science this year, especially my lessons on forces and friction. The children all appeared to enjoy the lessons and from my assessments they also achieved the objectives’

‘raring to go! I love teaching science’

Questionnaire

Comments confirm the findings from the audit. The experiences that the students have had of science, especially their experiences of teaching have been instrumental in their attitude change towards science.

‘I always found it quite boring but the fresh approach on the course has shown me that teaching science can be enjoyable’

‘I thought science was boring and difficult to teach. I realise now that science can be fun to teach and fun for children to learn. It can be taught enthusiastically using simple equipment’

‘I have completely changed my view of science, I hated it at school and now I enjoy teaching it!’

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End of course evaluations

To some extent the role models of the tutors and teachers in school are partly responsible for the students changed attitudes,

‘.. an inspiration to us all and I have been given great enthusiasm for teaching science in the primary classroom’

‘great to have such enthusiastic tutors who show how science can be really fun in schools’

‘It was really nice to be taught by enthusiastic creative people, made it far more enjoyable’

The comments indicate that the students have reflected on the changes the course has to them both personally and professionally,

‘I feel inspired to go and teach interesting science’

‘I really enjoyed the science course and it has really motivated me to teach science making it fun and to enthuse the children’

Discussion and implications

It would appear that the course prepares students well, in subject, pedagogical and curriculum knowledge to teach primary science as beginning teachers. This growth of competence in teacher knowledge seems to provide the students with increased confidence in their ability to teach effectively (Gooday et al. 1993). Furthermore, it would seem to alter negative attitudes towards science and teaching science by developing an inherent interest in science (Mulholland and Wallace 2003, Ryan 2003). The students indicate that they have enjoyed teaching science and that they are looking forward to the prospect of teaching primary science in their future careers. Science and science teaching has become an active and enjoyable aspect of their practice for these students. The enthusiasm and interest in science generated by these new teachers will hopefully motivate children to learn science and instil in those
children a desire to develop their own expertise in the subject. Indeed for some children it may help them make the decision to follow a career in science.

A constructivist approach to learning in which students have the opportunity for formal and informal reflection appears to enable students to think critically about their learning and understand that process so that they can develop further (Long and Stuart 2004). This meta-cognitive dimension to the process of learning should benefit the students not only within the teaching of primary science but throughout their teaching career as they hone the skills of reflective practice (Ryan, 2003). Teachers who behave and think like this will surely benefit children that they teach.

The course appears to go beyond training and educates students about primary science through a process that allows them to gain transferable knowledge and interpersonal skills. These processes appear to enable students to make judgements and critically analyse their progress, providing them with the basis for targets for further development and setting the expectation of continued professional development and for some the aspiration to become science subject leaders. More detailed information may offer a greater insight about how the course helps to fulfil the needs of student teachers and enables them to become effective primary science teachers. Further study is therefore necessary to elicit the extent to which the different aspects of ‘teacher knowledge’ are synthesised (Parker 2004) and embedded within the students’ practice. It is also important to stress that education is an ongoing process and that the students who leave this course will need to develop their skills and knowledge throughout their careers. Hopefully this course has provided them with the tools to begin to do that.
Perhaps the students should have the final word about the value of the course, these comments come from two very contrasting students, one a science ‘phobe’ (at least at the beginning of the course) and the other a science ‘phile’,

‘a fantastic course – it has changed my perception and attitude towards science completely, I left school hating it and now its highlighted as a strength in my observations and reviews.’

‘I already have an amazing passion for science, but this course helped me to really understand how I could transfer that to primary children – it was awesome folks!’

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DEVELOPMENTALLY AND PEDOGOGICALLY APPROPRIATE STATE SCIENCE STANDARDS

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Abstract: Science teachers, and elementary teachers who are teaching science, face many challenges in making appropriate decisions about science curriculum, instruction and assessment. While state curriculum frameworks and/or curriculum guides are intended to assist teachers in making these decisions, often these documents are inappropriate or less than helpful. In this paper we argue that the degree to which state science curriculum frameworks and standards improve science curriculum and instruction is determined by:

- The extent to which state science standards are developmentally appropriate;
- The extent to which state science standards convey to teachers and assessment developers the relative value or importance of various outcomes and the cognitive demand (Webb, 2002) expected for important topics and concepts so that teachers can align curriculum development, instruction and classroom assessment with state assessments;
- The extent to which the language used in state science standards helps teachers make instructional decisions consistent with the state documents.

Background

More than fifteen years ago Science for All Americans (AAAS, 1989) advocated scientific literacy as the stated goal for K–12 science education with a developmental, conceptual and “less is more” approach to achieving this goal.

The schools do not need to be asked to teach more and more content, but to teach less in order to teach it better. By concentrating on fewer topics, teachers can introduce ideas gradually, in a variety of contexts, reinforcing and extending them as students mature. Students will end up with richer insights and deeper understandings than they could hope to gain from a superficial exposure to more topics than they can assimilate (p. 21).

Following the publication of Science for All Americans, national science curriculum frameworks were developed based on the concept of scientific literacy. These documents included Benchmarks for Scientific Literacy (AAAS, 1993) and the National Science Education Standards (NRC, 1996). These three national documents then heavily influenced the subsequent development of state standards and ultimately state science curricula.
However, we believe that state science curriculum standards often do not represent the vision of science curriculum expressed in the national documents.

While the use of standards in science education is not a negative _per se_, the development and implementation of inappropriate state standards; the use of assessment mechanisms that do not match the standards; and/or failure to adequately convey to teachers the information that they need to align their curriculum with the state assessments may have combined to impede the achievement of scientific literacy.

**State Curriculum Frameworks Should be Developmentally Appropriate**

Over the last decade states, school districts and schools have been responding to ever-increasing demands for high standards. This phenomenon has been hailed by some teachers as “the rising tide of expectations”. These demands have been manifested in a variety of ways, including federal legislation, mandates and guidelines. For example, Title I legislation is aimed at supporting, “…states in setting high standards for all children…[through a] focus on teaching and learning, through upgrading curriculum, accelerating instruction, and providing teachers with professional development to teach to high standards” (USDE, 2001, p. 2). While US Department of Education documents consistently refer to the alignment of instruction and professional development with standards, little, if any, attention is paid to whether those standards are appropriate. The only concern seems to be with whether or not they are “high” standards.

As a result of these pressures, states are attempting to raise science standards. This “raising of standards” often results in a decrease in the grade level at which key concepts are addressed. _Benchmarks for Scientific Literacy_ specifically addresses this tendency when describing addressing the structure of matter, and indicates why it is counterproductive to do so.

Bringing atomic and molecular theory into the earlier grades is a great temptation, but most students are not ready to understand atomic theory before adolescence. The
theory is certainly essential to much of modern scientific explanation, but moving atomic/molecular theory forward to the earlier grades should be resisted. The tiny size and huge number of atoms in even a grain of sand are vastly beyond even adult experience. Having students memorize the names of invisible things and their parts gets things backwards and wastes time. Concrete perceptions must come before abstract explanations. Students need to be familiar with the physical and chemical properties of many different kinds of materials through firsthand experience before they can be expected to consider theories that explain them (1993, p. 75).

While both Benchmarks for Scientific Literacy and the National Science Education Standards recommend introducing the structure of matter gradually in K–8 and then addressing the structure of atoms in high school, some states such as California call for a significantly different approach. Below are excerpts from physical science standards for the state of California from 1990 and 2003. We believe that these documents demonstrate the movement of science content and concepts to inappropriately low grade levels.

K–3: Introduction of the terms: matter, mixture, pure substances. “Two substances can interact to form new substances with different observable properties.”

Grades 3–6: Introduction of the terms: matter, atoms, molecule (defined as a group of atoms tightly bound together), and chemical reactions (defined as the rearrangement of the atoms within molecules). Properties of atoms are explained as being related to the atoms of which they are comprised and the arrangement of those atoms. Matter is conserved in these chemical reactions. “Compounds have well-defined compositions involving new molecular combinations of whole numbers of atoms with new linkages.”

Grades 6–9: Introduction of the terms/concepts: physical properties, chemical properties, homogeneous compounds. Atoms are defined in terms of protons, neutrons and electrons. “In chemical reactions atoms are neither created nor destroyed. By using familiar symbols for atoms, the science student can convert this conservation principle to a useful bookkeeping method for atoms. Such chemical equations are useful for keeping track of or the quantities of substances involved by using mass as a measure of quantity.”

Grades 9–12: “The number and arrangement of electrically charged particles within atoms or molecules govern the predictable arrangements and rearrangements of the atoms in those new substances.” Introduction of metals, non-metals and semiconductors. Balanced chemical equations are introduced. (California Department of Education, 1990)

Grade 3: Introduction of the terms/concepts: matter, atom, elements, periodic table of the elements. “Atoms will be introduced as the smallest component of the elements that compose all matter. Students will learn that there are different kinds of atoms and that their names and symbols are displayed on the periodic table of elements.” “The important idea to convey is that all familiar substances are made of atoms, the term for the smallest particles of matter that retain the properties of the elements.” Students in
grade three should know that a chart exists that displays the names and symbols of
known elements and other information.”

Grade 5: Introduction of the terms/concepts: compounds, mixtures, chemical
properties, trends on the periodic table, atomic number, atomic weight, reactants,
products, metals, non-metals, and salts.

The standards also introduce chemical formulae. [Standard 1.g. Students know the
properties of solid liquid and gaseous substances, such as sugar (C₆H₁₂O₆), water
(H₂O…)] It is suggested that students use models to represent simple molecules such as:
nitrogen, oxygen, water, carbon dioxide, methane and propane. Students should
also be able to locate the constituent elements of a compound on the periodic table, for
example, sodium and chlorine as the atoms that comprise sodium chloride. (California
Department of Education, 2003)

Byrnes (2001) claims that, “…the primary goal of science is to reveal the causal
nature of the world” (p. 249). Similarly, one of the key goals of science education is to have
students develop an understanding of those causal relationships, as understood by scientists.

Further, students should understand why scientists have concluded that these concepts, ideas,
thories and laws are the best explanations available to help us understand the natural world.

However, McDevitt and Ormrod contend that, “Only with formal operational thinking can
people address and answer questions about cause-effect relationships in a truly scientific
fashion” (2002, p. 121). Thus, attempting to teach concepts that involve cause-effect
reasoning to students before they reach formal operations thinking may be unproductive and
possibly counterproductive. The formal operations stage of cognitive development typically
doesn’t appear in children until age 11 or 12 (Crain, 2005). A child’s formal operations
thinking is characterized by second order relations, analogical reasoning and abstract thought.

These cognitive capabilities are developed after the basic foundational skills of concrete
mental representations, conservation, reversibility, multiple classification and deductive
reasoning have been mastered.

When teachers attempt to address science concepts and relationships beyond the
comprehension of their students, they are forced to either resign themselves to being relatively
unsuccessful or teach the science curriculum at a very superficial level, wasting valuable
teaching time and student energy. This time could be better spent on rich hands-on science
activities that are developmentally appropriate for the cognitive skill level and capabilities of the concrete operational child. Thus we argue that the current California Science Content Standards for the structure of matter are an excellent example of “high standards” gone awry. We believe that high standards, in this case, should mean developing students who have a robust understanding of properties of materials, states of matter, temperature, etc. This experience and ideas with macro-level observable materials allows students to sharpen their basic scientific skills of observation, classification, and communicating while using their imagination to hypothesize about the existence of smaller micro-level particles that are too small to be seen (NAEYC, 1988).

By comparison, the 2001 Science Framework for Massachusetts Public Schools shows much better alignment with Benchmarks for Scientific Literacy and developmentally appropriate practice, with our understanding of the intellectual capabilities of students at various developmental stages, combined with curriculum experiences that scaffold students’ future understanding of the structure of atoms.

Grades 6–8: Recognize that there are more than 100 elements that combine in a multitude of ways to produce compounds that make up all of the living and nonliving things that we encounter. Differentiate between an atom (the smallest unit of an element that maintains the characteristics of that element) and a molecule (the smallest unit of a compound that maintains the characteristics of that compound). Give basic examples of elements and compounds. Differentiate between mixtures and pure substances. Differentiate between physical changes and chemical changes. (Massachusetts Department of Education, 2001)

The 2003 California Science Standards also introduce many life science concepts at grade levels below those recommended by Benchmarks for Scientific Literacy. For example, the balanced chemical equations for photosynthesis and cellular respiration are introduced in fifth grade life science. In seventh grade cell organelles are introduced, including cell membrane, cell wall, nucleus, chloroplasts, central vacuole, cytoskeleton, and mitochondria. The terms enzymes, chromosomal DNA and protein synthesis are also introduced in narrative
of the seventh grade Life Science standards. *Benchmarks for Scientific Literacy* does not suggest addressing cell organelles until high school.

A comparison of selected state science standards and National Assessment of Educational Progress (NAEP) science results provides evidence that may lend support to the developmental approach advocated by *Benchmarks for Science Literacy*. For example, grade 8 NAEP science results for 1996 and 2000 indicate that Vermont and Massachusetts, both of whom appear to have established content standards consistent with the Benchmarks scored very well. Conversely, California which has “higher” science standards had significantly lower results. While a variety of factors obviously contribute to state NAEP results, it does seem interesting that Vermont and Massachusetts NAEP results are favorable and increasing while California results are unfavorable and decreasing.

Table 1: Percentage of Grade 8 Public School Student Scoring Proficient or Above on the NAEP Assessment (NCES, 2001)

<table>
<thead>
<tr>
<th>State</th>
<th>1996</th>
<th>2000</th>
<th>Net Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>20</td>
<td>15</td>
<td>-5</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>37</td>
<td>42</td>
<td>+5</td>
</tr>
<tr>
<td>Vermont</td>
<td>34</td>
<td>40</td>
<td>+6</td>
</tr>
</tbody>
</table>

The Language of State Curriculum Frameworks Should Help Teachers Make Instructional Decisions

In order to increase students’ success, curriculum frameworks must help drive the curriculum. By that we mean that the language and structure of the frameworks increase the likelihood that teachers will make curriculum decisions that are consistent with the framework. For example, curriculum frameworks that address topics such as scientific inquiry or unifying themes in the learning targets rather than simply in the narratives would have this effect. Choices of verbs also can suggest both the level of cognitive demand and an appropriate pedagogical approach. A fourth-grade physical science unit on “light” might call for students to be able to define the terms transparent, translucent and opaque. A curriculum
standard that requires that students be able to, “investigate how a beam of light interacts with
a variety of objects in order to determine whether the object casts shadows, allows light to
pass, or reflect light” (CMEC, 1997, p. 145) sends a very different message about the sorts of
learning activities in which students should be engaged.

Heavy emphasis on scientific terms in curriculum guides can lead teachers, especially
at the elementary and middle school level, to approach the teaching of science as a vocabulary
list to memorize. Curriculum guides can either help minimize this effect by describing what is
to be learned in a conceptual basis or exacerbate the situation.

State Curriculum Frameworks Should Help Teachers and Assessment Developers Set
Priorities

Given the impact of high-stakes testing on classrooms, curriculum frameworks must
provide teachers with information that will allow them to make decisions about curriculum
priorities and allow them to align instruction with classroom, local and state-level
assessments. However, state standards can resemble a laundry list of undifferentiated
outcomes and standards. Teachers make curriculum decisions on the basis of these
undifferentiated lists, as do state assessment developers. If the state assessment developer’s
interpretation of the standards differs greatly from the classroom teacher’s, students (and
therefore schools) who have been successful at learning the enacted curriculum may still score
poorly on the state assessment.

*Benches for Scientific Literacy* argues that curriculum documents should help
teachers determine what learning is “essential” and thus deserve an approach different from
other outcomes or standards. Similarly, Wiggins and McTighe (1998) argue that teachers
must establish curriculum priorities. That is, teachers must differentiate between learning
targets that are enduring understandings, important to know and do, and worth being familiar
with. Wiggins and McTighe also argue that teachers must learn to think like assessors by considering the types of evidence that can be used to determine that learning targets have been achieved and matching assessment strategies to the type of learning target. However, they describe these decisions as being made primarily by the teacher.

Porter and Smithson (2001) argue that successful instruction involves, among other things, the alignment of state curriculum frameworks and policies (the intended curriculum), the curricular content that students engage in (the enacted curriculum), what students actually learned (the learned curriculum), and how student learning is assessed (the assessed curriculum). This assessment includes both classroom assessment and high-stakes external assessments. We agree with Porter and Smithson that this is desirable and possible, providing that the curriculum standards utilize the three criteria that we have established.

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California Department of Education (2003). Science Framework for California Public Schools Kindergarten Through Grade Twelve, Sacramento, CA


http://facstaff.wcer.wisc.edu/normw/All%20content%20areas%20%20DOK%20levels%2038202.doc

THE MANY DIMENSIONS OF VOLUME

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Abstract
Pre-service teachers (PTs) in science and mathematics methods courses must build content and pedagogical knowledge as well as pedagogical content knowledge. The study of volume is a rich context for reaching all areas. Within this context PTs develop lessons on volume and do action research projects with individual children.

Background
Pedagogical beliefs of pre-service elementary teachers are often at odds with the teaching practices espoused in the National Science Education Standards (National Research Council, 1996) and the National Mathematics Standards (National Council of Teachers of Mathematics, 2000). They often come to methods courses in science and mathematics with an orientation toward transmission of knowledge rather than knowledge construction (Flick, 1996; Hill, 1997; Holt-Reynolds, 1992; Stofflett, 1994). So, the construction of pedagogical concepts is of primary importance in a science and mathematics methods course. Pre-service teachers (PTs) must understand how children construct knowledge and how to facilitate children’s knowledge construction.

Bruner (1990) posits that the mind reaches its full potential only through involvement in culture, and he advocates narrative as instrumental in meaning making. Within the culture of education, action research and reflection can be tools for meaning making with respect to teaching and learning (Mills, 2000). Action research and reflection may also be important components in helping PTs make sense of the complexities of teaching (Zeichner & Liston, 1996; Munby and Russell, 1990; Nichols, Tippins, & Wieseman, 1997; van Zee & Roberts, 2001). If PTs are to make sense of the teaching practices espoused in the standards they should be involved in authentic teaching experiences; by reflecting on and sharing narratives of such experiences, the experiences gain meaning.
Pre-service elementary teachers must also have meaningful understanding of the content that they will teach, and science and mathematics content knowledge is often weak (Doyle & Alagic, 2004b; Watters & Ginns 2000). Because the time available in methods courses is often very limited, it is essential to consider the need to deepen content knowledge alongside the need to build pedagogical knowledge. Ideally, an authentic teaching experience is also an opportunity to build content knowledge in science and mathematics. Such convergence of experience might also generate important pedagogical content knowledge, that is, knowledge of how to best facilitate construction of content knowledge of a specific topic (Smith, 1999).

Inquiries into Knowledge and Learning

Teachers’ Inquiry into Children's Knowledge and Learning Evolvement (TICKLE) is a project that was developed over a period of three years to directly involve pre-service elementary teachers in the culture of education (Haack & Alagic, 2003; Doyle & Alagic 2004a). The project is based on the philosophy that learning is best facilitated by recognizing each child in a classroom as an individual; the culture of teaching is a culture of teaching individual children. Thus, TICKLE provides an ongoing experience with a single learner. The nature of the TICKLE project is deepened by elements of reflective practice (Abell & Bryan, 1997) and by placing the preservice teacher in the position of researcher (Pekarek, Krockover, & Shepardson, 1996; Van Zee, 1998; Watters & Ginns, 2000). Each pre-service elementary teacher plans four sessions with a child in the age range of 5-12 years, and then produces a written narration and interpretation of each of the sessions. The first session with the child is devoted to completion of Piagetian tasks that gauge the child’s logico-mathematical development. Then prior to each of the other sessions the related mathematics and science content is treated in class with approximately 90 minutes of related concrete,
hands-on activities and discussion. Based on one or more of these activities, the PT designs a lesson for her/his TICKLE session. Following each session, class time is devoted to debriefing, and there are online discussions within groups of pre-service teachers.

**Lessons in Volume and Pedagogy**

Volume has proven to be an especially rich topic within the TICKLE project. As content it falls within the domains of both science and mathematics. Spatial reasoning in two and three dimensions is encouraged. Ideas surface about measurement, and the ideas connect to generation of formulas.

Pre-service teachers complete a progression of four activities in the classroom before they decide on the lessons that they will develop for their individual students:

1. Arrange 5 containers of various shapes and sizes in order of capacity, and then use rice to test the order.
2. Make boxes (pattern provided) that can be measured in even centimeters. Fill each box with centimeter cubes to find the volume. Use rice to compare the volume of a box with the volume of a small jar. (See Appendix A.)
3. Use cubes placed on grids to build rectangular pyramids, and find the relationship between the number of cubes in each row and column as well as the number of layers to derive a formula for volume of any rectangular pyramid. (Surface area has sometimes been incorporated into this activity.
4. Form 2 cylinders by folding pieces of letter-size card stock, so that one cylinder is thinner and taller than the other.

The first activity, arranging containers, is seemingly simple, but it builds on the results of the Piagetian tasks that were completed in the first TICKLE experience. Predictably, a number of children do not conserve liquid amount. That is, when liquid is poured from a short wide container into a tall narrow container, they perceive that, since the liquid level is higher...
in the narrow container, there is more liquid. Because the child centers on a single dimension of the container, arranging containers according to their capacity is a challenge.

The container activity raises fundamental questions of lesson design such as consideration of developmental level and prior knowledge, goal setting, and appropriate assessment. The first reaction of many if not most PTs is that the goal of a container arranging activity is to learn to arrange containers. It follows that if the child can arrange the containers in correct order, the goal has been met. What are the goals we want them to consider? Possibilities are

- The student will use more than one dimension to determine the capacity of a container, or
- The student will be able to explain the expected result when using rice (or other material) to check the capacity of one container against another.

These are goals that lend themselves to the design of instruction. PTs who choose the goal of arranging containers in order generally lead the child through arranging and testing with little regard to teaching. However, if they focus on use of more than one dimension, they have a focus for their efforts. If testing the capacity of one container against another is important, they know that they have to plan for explicit predictions within their lesson.

Assessment of the container activity is also rich with possibilities for learning about assessment. It is an opportunity to ask how the child’s explanations might be judged. It is also an opportunity for considering what constitutes a summative assessment. Most PTs in our classes think of pencil and paper tests as summative assessment, and the idea of performance assessment in the form of a task is relatively new to them. The container activity lends itself to testing transfer of learning to a new task. The difference in the task may be as simple as a change of materials, for instance water instead of rice, or it may be a change in containers.
Finally, the container task also generates questions about the place of vocabulary in teaching science and mathematics. Among PTs the initial idea of pre-assessment for the volume activities begins with the question, “What is volume?” Aside from their surprise at answers that refer to buttons on televisions and radios, they conclude that lack of a clear definition signifies lack of knowledge about volume. One PT punctuated an entire set of container activities with a repeated definition of volume. The definition was interjected with little connection to the activities, and the PT was disappointed that her six-year-old student could not repeat the definition in the end.

Precision of vocabulary is also an issue that arises, as it does often in mathematics and science contexts. What do the words *size* and *biggest* mean in relation to volume? To a significant number of PTs, these words are used interchangeably with height, and so they may in fact share and even reinforce their students’ tendency to center on height. It is not uncommon for a PT to report, “[The child] was focusing on the size of the container instead of how much it held.”

As a vehicle for pedagogical development, the simple container activity is easily related to a whole range of issues. Also, at a very fundamental level, pre-service teachers are confronted with the problems of “packaging” a lesson in a practical way, for instance making a choice of rice or water as a medium for hands-on activity. This activity does not, however, provide much challenge with respect to content development. Science and mathematics concepts play a much larger role in the subsequent activities.

**Lessons in Volume and Content Knowledge**

Experience over the period of three years has revealed that the majority of PTs identify two definitions of volume. There is what they consider an *informal* definition: the amount of space occupied by an object or the amount that can be held by a container. There is also a *formal* definition: length × width × height. The latter formula is almost always given
without consideration of its limitations. The second and third volume activities address this common misconception.

In the second activity PTs cut out patterns (Appendix A) and build boxes that are measurable in centimeter increments. They are also given a bag of centimeter cubes, which they measure and identify as cubic centimeters. They predict the relative capacities of the boxes and then fill each box to find that they all hold 24 cubic centimeters. At this point there is general recognition that, yes, they could have foretold this by using length \( \times \) width \( \times \) height. The tie to their favorite formula is easily made. The tie to the amount of rice held by a container is made through a challenge: use rice to find the capacity of a small jar in cubic centimeters. Thus the dual definitions of volume are exposed and united.

The box activity also adds another pedagogical element: conceptual knowledge develops. That is, concepts are built step by step, and the steps must be connected. The connection of cubic measurement with the “fluid” capacity measured by rice is a model for development of other concepts. Simple ideas like the amount of rice that will fit in a container are important prior knowledge, and that prior knowledge must be explicitly connected to new knowledge.

The third activity addresses the roots of the formula for a rectangular prism. (See Appendix B.) By building rectangular prisms layer by layer on a grid, PTs generate the length \( \times \) width \( \times \) height formula. In the first semester of the TICKLE activities, instructors naively believed that PTs would be able to explain the logic of the formula and its limits as a result of this activity. This result was rare. For most PTs another step was required: an examination of area. The first step in using the grid activity must be the development for the formula for area. If this happens before cubes are placed on the sheet, most PTs can make the transfer to volume when cubes are added.
Two points must be noted with respect to the content knowledge addressed in the box and grid activities. First, the confusion between area and volume may be more prevalent than most science and mathematics educators suspect. Perhaps part of the problem is the common use of the word \textit{area} to designate a space, e.g., “that \textit{area} of the room.” Second, learners may never feel confident of their understanding of volume until they make the connections among fluid capacity and cubic measurement and the familiar formulas for volume and area. We were at first confused when PTs would complete successful TICKLE lessons but still confess that they did not \textit{understand} volume. Our conclusion was that they were not making the connections, and we had to improve the preparatory activities to help PTs clarify the connections.

The final classroom preparatory activity involves cylinders created by rolling and taping two pieces of 9” × 12” construction paper to form cylinders of different dimensions. PTs then predict which cylinder; the tall, thin cylinder or the shorter, wider cylinder; will hold more rice. The instructors have used the cylinder activity as a final challenge during class or as a question to take home and discuss in the next class meeting. In either case it is a means of assessment. Most PTs assume that the same surface area will result in the same capacity. In other words, they ignore the basic concept of the first activity. However, the great advantage of this activity turns out to be in the area of pedagogical content knowledge. When students are allowed to take the activity home, a number of them predictably neglect to test their predictions. They learn a basic lesson of science when they advance their \textit{untested} predictions during the quiz that follows in the next class session.

\textbf{Lessons Learned}

The first implication of the experiences with volume applies to conceptual understanding and is important to science education in general. Density is a basic concept in
science, and a formal understanding of density depends on an understanding of volume. The indicated lack of understanding of volume is a major concern. Such understanding must not be taken for granted. It should be emphasized as a precursor to any development and use of the density concept.

The second implication is that it is possible to find foundational activities that can further a wide variety of goals in science and mathematics methods courses. The volume activities fit this description. As science and mathematics educators consider their choices, three questions should be asked:

1. What are the pedagogical concepts are modeled?
2. What content is developed?
3. What content misconceptions exist and what connections might help?

Pre-service teacher responses to the volume activities show significant growth in pedagogical knowledge and in content understanding as they complete the volume activities in class and then with their own students. There are some ahah moments in class, and more ahah moments that appear in the reflective papers. Each PT works with an individual with a unique developmental level and under unique circumstances. Thus each of the pre-service teachers holds unique pieces of the puzzle, but they are only pieces. Our job as instructors is to help them fit the pieces together. The meaning making begins in class, advances in their individual narratives and interpretations, but it must also include a culminating group process in which they share and refine their thinking.

References


Appendix A

Patterns for 24-cm³ boxes

Appendix B

Grid Activity
DIRECTIONS

1. Cover Grid A with cubic centimeter blocks. Record the number of blocks in the data table below.

2. Make a second layer of blocks on Grid A. Record the TOTAL number of blocks in the data table.

3. Make a third layer of blocks on Grid A, and record the total number in the data table.

4. Repeat the process with Grid B.

5. Repeat the process with Grid C.

Data Table

<table>
<thead>
<tr>
<th>Grid</th>
<th>Number of cubic centimeter blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One layer</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

Describe the patterns in the data.
What do they know?  
A look into preservice teachers' earth science content knowledge  

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Abstract

Content knowledge is one of the primary focuses of teacher certification. This pilot study assessed the earth science content knowledge of 82 preservice Master of Arts in Teaching interns at the University of Arkansas. We examined preservice teachers' content knowledge, alternative conceptions, and scientific understandings as well as ways science educators can address these issues. Our purpose in this study was to gain evidence of possible alternative conceptions held by our interns, which could affect their classroom practice when they become teachers. Our findings indicate that a majority of our preservice teachers may still hold alternative conceptions in various aspects of earth science. Our participants overall also expressed a lack of confidence in their answers and a lack of understanding of many of the concepts presented.

What do they know? A look into preservice teachers’ earth science content knowledge

“…to teach the solar eclipse I would bring in many hands on materials. I would also hold a night session to watch a solar eclipse.”
-Pre-service Teacher

Theoretical background

The above quote is one of several from our research that demonstrates a lack of content knowledge prevalent in preservice teachers. Content knowledge is one area of primary focus for teacher certification programs. The practice of testing preservice teachers' content knowledge can be traced back several hundred years (Wilder, 1941). Research from the past two decades has shown strides being made in connecting content knowledge to instruction (Wilson, Shulman, & Richart, 1987; Aubrey, 1996; Kallery & Psillos 2001). This is in part, due to Shulman's (1986, 1987) theoretical development of pedagogical content knowledge (PCK).

Science teacher educators do recognize that content knowledge plays an integral part in successful teaching. Findings in a project conducted by the National Research Council (NRC) (1996) encouraged science education faculty to “structure the content, pedagogy, and
assessment strategies in science courses, especially in the lower division, to optimize student learning, thereby providing future teachers with the knowledge, understanding, and skills necessary to teach in accordance with the Standards” (NRC, 1996, p. 6). With this in mind, we should "reexamine our assumption that subject matter knowledge required for teaching can be acquired solely through courses taken in the appropriate university department" (Grossman, Wilson, & Shulman, 1989, p. 23). We need to be conscious of preservice teachers' need to develop their own understanding about scientific concepts and possible misconceptions they may bring to the learning environment.

Many terms are used to describe the phenomenon of nonscientific conceptions in the learning environment. Some of these include misconceptions, naive beliefs, persistent pitfalls, science fragments, to name a few (Wandersee, Mintzes, & Novak, 1994). For this study we are choosing to use the term alternative conceptions, defined as scientific ideas of the individual that do not match current scientific understandings to represent these ideas. We chose this definition because it recognizes the learner as an individual trying to make sense of the world with understandings that they have constructed that work for them.

Alternative conceptions affect the teaching and learning processes. Identifying students’ alternative conceptions can serve as a starting point for instruction. If we can identify areas of common alternative conceptions, we can begin to address areas of content knowledge that need to be focused on in methods courses. The lecture based teaching we commonly receive in content courses often serves to reinforce alternative conceptions that students bring to the learning situation. Marques & Thompson (1997) indicate that ‘normal teaching’ does not help to eradicate alternative conceptions, stated another way, you cannot teach away misconceptions (Wandersee, Mintzes, & Novak, 1994). Another source of alternative conceptions is “science myths, which circulate in the popular culture, which are handed down from parents to children, and which have become so common and widespread
that they even appear in science textbooks and are taught as facts in elementary school” (Beaty, 1996 Online). Lack of content knowledge is yet another source of alternative conceptions.

Recent studies show that teachers feel they lack specific content knowledge (Smith & Neale, 1989; Parker & Heywood, 2000; Kallery & Psillos, 2001). One study reports that nearly 75% of math and science teachers see a need within themselves to increase their content knowledge in the area of science (Weiss, Banilower, McMahon, & Smith, 2001). Other studies indicate that the amount of content knowledge of the individual influences the processes of planning, organizing, implementing, and presenting lessons (Leinhardt & Smith, 1985; Hashweh, 1987; Smith & Neale, 1989; Osborne & Simon, 1996). Content knowledge also impacts the nature of questions asked by the teacher, and has an effect on the levels of discourse shared between teacher and student (Carlson, 1988, 1991; Newton & Newton, 2001).

We cannot assume that preservice teachers ‘get’ the science knowledge needed to be effective science teachers in their college content area classes. Many of these classes are not taught for conceptual change. By assessing what these preservice teachers know, we can better meet their needs via more effective content courses and better developed methods courses. We can help them to address deficits in their own earth science content knowledge, and thereby help them to be active and reflective in their pursuit of teaching for understanding. Hickey (1997) points out that we can not expect teachers to learn with the students, but we must encourage them to “take a more active role in ascertaining their own knowledge and determining if it is adequate to promote their students learning” (p. 3). This includes the areas of content knowledge and alternative conceptions in science. Several researchers have indicated that often teachers share the SAME alternative conceptions that their students hold (Smith & Neale, 1989; Wandersee, Mintzes, & Novak, 1994; Harlen,
Holroyd, & Byrne, 1995; Parker & Heywood, 2000). We hope that by assessing the alternative conceptions held by the preservice teachers we can facilitate conceptual change, thereby improving their classroom practice when they become teachers.

Earth science is the one content area that is present at all levels of the Arkansas Science Frameworks, and is therefore required to be taught at all levels. We have chosen to assess and examine the earth science content knowledge of preservice teachers enrolled in the Master of Arts in Teaching (MAT) program at the University of Arkansas, Fayetteville. We hope to unearth what preservice teachers know about specific earth science concepts based on National Science Education Standards (NSES) and Arkansas Science Frameworks.

The research questions driving this study are: 1) What do preservice master’s level interns at the University of Arkansas know about specific earth science concepts based on National Science Education Standards and Arkansas Science Frameworks? And 2) what is the nature of preservice teachers’ content knowledge, alternative conceptions, and scientific understandings? We hope to gain insight into preservice teachers' content knowledge, alternative conceptions, and scientific understandings as well as ways science educators can address these issues.

Participants

Participants for this pilot study included 82 MAT interns at the University of Arkansas, Fayetteville. These MAT interns have completed their college content courses and their bachelor’s degrees and are currently serving a year of preservice teaching while taking their master’s level course work. These MAT interns come from a variety of undergraduate degree backgrounds and are pursuing a variety of certification levels. Table 1 delineates these.

Table 1

<table>
<thead>
<tr>
<th>MAT intern degrees and certification levels</th>
<th>Percentage of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary Education</td>
<td>50%</td>
</tr>
<tr>
<td>Hard Science (Biology, Physics, Chemistry)</td>
<td>3.7%</td>
</tr>
<tr>
<td>Soft Sciences (Political Science, History)</td>
<td>14.4%</td>
</tr>
</tbody>
</table>
Because of these students’ wide spread undergraduate degree programs, the range of the number of science classes is quite large. Our students had a range of two to 27 science classes with nearly 65% of them having 2 or 3 classes in science. We discovered that the number of earth science courses ranged from zero to three. Fifty percent of our students have taken one earth science course and 34% of our students have taken two earth science courses.

Eighty-four percent of these participants are women and 16% are men. Their ages range from 21 to 55 years old with a mean age of 26 years.

Instrument

The earth science content knowledge of our MAT interns was assessed by a “two-tiered diagnostic instrument” (Franklin, 1992) based on content standards delineated by National Science Education Standards (NSES) as well as the Arkansas Science Frameworks. This multiple choice test was patterned partly after the Misconceptions Identification in Science Questionnaire (MISQ) (Franklin, 1992) and was designed to assess knowledge, understanding, and confidence in Earth science content. The Alternative Conceptions in Earth Sciences – A Questionnaire (ACES-Q) consists of ten multiple choice questions. Each question consists of a diagram and written description of the situation or event, a question related to the event, a list of possible answers to the question, a list of possible reasons for the chosen answer, and two Likert scales to assess whether or not the concept made sense and how sure the participant was about his/her answers. The ACES-Q concludes with an opened ended question requesting the participants to share how they would teach “solar eclipses” for the grade level of their choice. We also included a series of demographic questions.
Validity and Reliability

Face validity was determined by subjecting the ACES-Q to the scrutiny of three professionals in the field of science education. These experts included an elementary science coordinator, a geology professor, and an elementary and middle level science education professor.

Overall test reliability was determined to be 0.76 using the KR-20 formula. Nunnally (1970) states that an acceptable test reliability coefficient should be greater than or equal to 0.70. Our instrument lies within the accepted range for reliability. Researchers will continue with item analysis to identify items with the best ability to discriminate among participants taking the questionnaire. This information will be used to consider whether certain distracters are discriminating between participants who do and do not know the answers.

Procedure

During the fall semester of 2004, participants were identified via enrollment in their MAT fall courses. The researchers met with each level of MAT interns to inform them of the assessment and to gain their consent to participate.

Data were gathered and then examined with several factors in mind (gender, age, certification level, undergraduate degree, college science courses taken, and earth science courses). The researchers focused on analyzing similarities and differences of test scores across these subgroups.

Results

Quantitative Data

Each of the ten questions was designed to assess the content knowledge of a particular concept in earth science. Table 2 below shows the specific concepts tested by the corresponding question number followed by the percentage of participants who chose a correct answer, correct response and, using a Likert scale, the means of the levels of
confidence in the respondents answer (1=just a blind guess…5=I am sure I am right) and levels of sensibility for the reason provided (1=makes no sense…5=makes perfect sense) were calculated.

Table 2
Questions on the ACES-Q

<table>
<thead>
<tr>
<th>Question</th>
<th>Concept</th>
<th>Answer Correct</th>
<th>Reason Correct</th>
<th>Confidence Mean (1-5 scale)</th>
<th>Sensibility Mean (1-5 scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Seasons</td>
<td>64.6%</td>
<td>42.7%</td>
<td>2.7</td>
<td>2.9</td>
</tr>
<tr>
<td>2</td>
<td>Sky Color</td>
<td>93.8%</td>
<td>46.9%</td>
<td>3.6</td>
<td>2.9</td>
</tr>
<tr>
<td>3</td>
<td>Gravity</td>
<td>56.1%</td>
<td>57.3%</td>
<td>2.8</td>
<td>3.0</td>
</tr>
<tr>
<td>4</td>
<td>Density</td>
<td>89.0%</td>
<td>45.7%</td>
<td>3.7</td>
<td>3.3</td>
</tr>
<tr>
<td>5</td>
<td>Biomes</td>
<td>10.9%</td>
<td>10.9%</td>
<td>3.6</td>
<td>3.8</td>
</tr>
<tr>
<td>6</td>
<td>River Formation</td>
<td>74.4%</td>
<td>39.0%</td>
<td>2.8</td>
<td>3.0</td>
</tr>
<tr>
<td>7</td>
<td>Minerals</td>
<td>50.0%</td>
<td>84.2%</td>
<td>3.0</td>
<td>3.4</td>
</tr>
<tr>
<td>8</td>
<td>Rock Types</td>
<td>63.4%</td>
<td>64.6%</td>
<td>2.8</td>
<td>3.1</td>
</tr>
<tr>
<td>9</td>
<td>Salinity of Water</td>
<td>50.0%</td>
<td>32.5%</td>
<td>2.4</td>
<td>2.7</td>
</tr>
<tr>
<td>10</td>
<td>Water Run-Off</td>
<td>91.5%</td>
<td>79.3%</td>
<td>2.8</td>
<td>3.0</td>
</tr>
</tbody>
</table>

The table above shows, on nine of ten questions, over 50% of participants chose a correct answer. However, on six of ten questions, despite choosing the correct answer, participants were unable to choose the correct scientific explanation for that phenomenon. This indicates to us that more than half of our participants possibly still hold alternative conceptions in earth science.

Question five asked participants to choose a biome that best represented Antarctica. Less than 11% of participants chose desert while 66% chose the distracter tundra, despite the wording of the question that indicated tundra was located in the Northern Hemisphere. This surprised us because this question had one of the highest confidence and sensibility ratings of the ten questions. Also, we thought that participants would know that Antarctica was located in the Southern Hemisphere.

Question seven asked participants to choose a mineral that would best scratch glass based on Mohs Hardness Scale. While only 50% of participants got the answer correct, 84%
chose the correct scientific explanation. The counterintuitive nature of the responses from our participants indicates a need to take a closer look at this question.

Table 3 shows the participant’s mean scores for answer, response, total score, confidence, and sensibility. The answer and response scores were calculated by the number of correct choices out ten possible choices. The total score was arrived at by summing the answer and response scores. The confidence and sensibility scores were created by summing the numbers chosen by participants on the five point Likert “sure” and “sense” scales for each of the ten questions. The possible range was five to 50.

Table 3

<table>
<thead>
<tr>
<th>ACES-Q means</th>
<th>N</th>
<th>$\bar{X}$</th>
<th>sd</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answer</td>
<td>82</td>
<td>6.5</td>
<td>1.7</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Response</td>
<td>82</td>
<td>5.1</td>
<td>2.1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Total Score</td>
<td>82</td>
<td>11.6</td>
<td>3.4</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Confidence</td>
<td>82</td>
<td>30.3</td>
<td>7.7</td>
<td>10</td>
<td>48</td>
</tr>
<tr>
<td>Sensibility</td>
<td>82</td>
<td>31.0</td>
<td>8.6</td>
<td>10</td>
<td>48</td>
</tr>
</tbody>
</table>

Inspection of the means (Table 4) showed differences among all subgroups. On average, men scored higher than women on the ACES-Q. Preservice teachers pursuing high school certification scored higher than preservice teachers pursuing elementary and middle level certification with preservice middle level teachers having the lowest mean. Students with undergraduate degrees in hard sciences (biology, physics, chemistry) and soft sciences (history, political science, sociology, anthropology) had the highest means while middle level and mathematics majors had the lowest means. Participants with the greatest number of earth science courses had the highest means.

Table 4

<table>
<thead>
<tr>
<th>Means according to subgroups</th>
<th>N</th>
<th>Mean</th>
<th>Sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>68</td>
<td>11.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Male</td>
<td>13</td>
<td>14.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Certification Level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>41</td>
<td>11.2</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Correlations among the confidence, sensibility, total score, and total science courses taken were examined for relationships (Table 5). No statistically significant correlations exist between total science and total score (p<.05). However, a moderate to strong, positive and significant correlation exists between several of the variables: total score correlated with sensibility and confidence, total science correlated with sensibility and confidence, and sensibility and confidence correlated with each other.

Table 5

<table>
<thead>
<tr>
<th></th>
<th>Total Score</th>
<th>Sensibility</th>
<th>Confidence</th>
<th>Total Science Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Score</td>
<td>1.0</td>
<td>.46*</td>
<td>.46*</td>
<td>.14</td>
</tr>
<tr>
<td>Sensibility</td>
<td>1.0</td>
<td>.75*</td>
<td></td>
<td>.33*</td>
</tr>
<tr>
<td>Confidence</td>
<td>1.0</td>
<td></td>
<td>.34*</td>
<td></td>
</tr>
<tr>
<td>Total Science Courses</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

n=81 *p<.05

Qualitative Data

One question on the ACES-Q was designed to allow participants to share their thoughts regarding teaching and content. Of our 82 participants only 75 chose to answer this question. Several salient themes emerged as we coded the responses from the participants. These themes were divided into the following sections: pedagogy and content knowledge. A list of several reoccurring themes and their frequency can be found in Table 7 below.
Table 7

<table>
<thead>
<tr>
<th>Pedagogy</th>
<th>Content Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explore, Research, Investigate (10)</td>
<td>Sun Covers Moon (2)</td>
</tr>
<tr>
<td>Models and Hands-on Activities (46)</td>
<td>Moon Covers Sun (5)</td>
</tr>
<tr>
<td>KWL Chart or Assessing Prior Knowledge (7)</td>
<td>Solar System (3)</td>
</tr>
<tr>
<td>Explain, Lecture, Tell (11)</td>
<td>Sun’s Rays (2)</td>
</tr>
<tr>
<td>Write or Essay (5)</td>
<td>Earth’s Rotation (3)</td>
</tr>
<tr>
<td>Representations (5)</td>
<td>Earth’s Revolution</td>
</tr>
<tr>
<td>Look or Observe (4)</td>
<td>Shadow (3)</td>
</tr>
<tr>
<td>Project, Present, or Create (9)</td>
<td>Lunar and Solar Eclipses (5)</td>
</tr>
<tr>
<td>Media (41)</td>
<td>Partial or Full</td>
</tr>
<tr>
<td>Technology, WebQuest, Internet, Video,</td>
<td></td>
</tr>
<tr>
<td>Posters, Overheads, Computer, Movies</td>
<td></td>
</tr>
<tr>
<td>Light Source or Flashlight (18)</td>
<td></td>
</tr>
<tr>
<td>Groups of Students (6)</td>
<td></td>
</tr>
<tr>
<td>Literature (12)</td>
<td></td>
</tr>
</tbody>
</table>

Several of the participants responded in a way that allowed us to discover if they held alternative conceptions or scientific understandings. Six of the 75 participants answered with a plainly stated alternative conception. Some examples of common answers follow:

- “I would set it (a model) up so that when the planet covers the sun, they could see the eclipse.”

- “I would explain that a solar eclipse is when the sun passes between the earth and the moon…”

- “I would hold a night session to watch a solar eclipse.”

Six answered with a clearly stated scientific understanding. Some examples of these include:

- “I would construct a model using balls to represent the earth, sun, and moon to demonstrate that a solar eclipse is when the sun, moon, and earth are all in line- the moon in between, blocking the sun completely from the earth’s view.”

- “…I would tell them that the moon and sun line up and cause an eclipse…”

- “I would (using a model) set the light so that it shines on the globe and then slowly move the ball through the light path. I would call attention to the shadow created on the globe…”

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These twelve responses were examined to see if there were any similarities or differences in pedagogical choices based on the content knowledge.

Six participants with alternative conceptions mentioned using models (2), pictures (2), and media (2). Six participants with scientific understandings mentioned the same, but with a greater frequency: models (4), visual aids (2), media (3). These students also went on to mention assessment of prior knowledge, using demonstrations (4), creating learning centers, and using various forms of literature (2)

Discussion

The two major questions addressed by this research were 1) What is the nature of preservice teachers’ content knowledge, alternative conceptions, and scientific understandings in earth science? and 2) What do preservice master’s level interns at the University of Arkansas know about specific earth science concepts based on National Science Education Standards and Arkansas Science Frameworks?

In our efforts to answer our first question our findings indicate that a majority of our preservice teachers may still hold alternative conceptions in various aspects of earth science. Nearly half of our participants still believe that the earth travels in a highly elliptical orbit and that the earth’s proximity to the sun causes the change of the seasons. Other areas where misconceptions seemed prevalent were gravity, biomes, river formation, minerals, rock formation, and salinity of water. These alternative conceptions are not unique to our participants. Several studies (Schoon, 1988, 1992; Callison, 1993; Atwood & Atwood, 1996; Schoon & Boone, 1998; Trundle, 1999; Trundle, Atwood & Christopher, 2002, 2003) concur that children, adults, preservice and seasoned teachers continue to hold their alternative conceptions in areas of earth science. In addition to these possible misconceptions, our participants overall expressed a lack of confidence in their answers and a lack of understanding of many of the concepts presented in the ACES-Q.
Our results showed us that for our second question, the interns showed familiarity with about half of the content presented on the ACES-Q. The ACES-Q represents a mere fraction of the science content addressed in the NSES and the Arkansas Frameworks. This concerns us as most of our interns intend to teach somewhere in the state of Arkansas and familiarity with the standards is an important part of their profession. Arkansas is currently in the process of implementing a new science benchmark test for public school students. This will be a major change as science has been pushed to the back burner in many schools, so our interns’ content knowledge and PCK in science could play a large role in job responsibilities.

Further investigation of the data is necessary. Researchers will continue by analyzing the data via the general linear model. These ANOVAs will allow us to interpret if the differences in means among the subgroups are significant and if further investigation is warranted. The data will also be analyzed using the regression model to discover which of the variables serve as the best predictors for performance on the ACES-Q.

This pilot study fits into the areas of science methods course content revision, preservice teacher preparation in planning and implementing lessons, and reflective practice. This data will allow science teachers and teacher educators at the University of Arkansas to become familiar with areas of earth science content that are not being addressed in content courses. Hopefully this will help create a partnership with the education and science departments within and across universities to create classes that will address students’ prior knowledge and teach for the conceptual change and scientific understanding of all students.

References


A PRELIMINARY ANALYSIS OF THE ANALOGIES IN SCIENCE TEACHING INSTRUMENT IMPLEMENTATION

Peter Rillero, College of Teacher Education and Leadership, Arizona State University

Abstract

This was an exploratory study of the first time use of the Analogies in Science Teaching instrument developed as a part of a four-university study (N=156) of the use of analogies in preservice science teacher education classes. The instrument was used as a pretest at the start of the Fall 2004 semester and as a posttest at the conclusion of the semester.

The main part of the instrument consisted of 23 Likert items that were written to contain seven main variables. Part two of the instrument contained background information items. The complete instrument is reproduced in the appendix of this paper. The instrument and most of the variables had satisfactory reliability scores.

The Analogies in Science Teaching instrument served a useful purpose in the first stage of a four-university study on the use of analogies in preservice elementary and secondary teacher education programs. The data suggest there were successes in helping preservice teachers learn about analogies. The secondary education students had higher pretest scores on the variables than did the elementary education students. The elementary education students had larger increases in the posttest scores.

Introduction

This was an exploratory study of the first time use of the Analogies in Science Teaching instrument developed as a part of a four-university study (N=156) of the use of analogies in preservice science teacher education classes. The instrument was used as a pretest at the start of the Fall 2004 semester and as a posttest at the conclusion of the semester.

The Instrument

The main part of the instrument consisted of 23 Likert items that were written to contain seven main variables. All Likert items contained a five point scale with 1, 2, 3, 4, and 5 representing strongly disagree, disagree, undecided, agree, and strongly agree, respectively. Part two of the instrument contained background information items. The complete instrument is reproduced in the appendix of this paper.

The seven variables in Part One, the abbreviated names, and the items that they consist of are as follows.

1. Personal Efficacy for Using Analogies (Efficacy for Using, items 3, 10, and 17)
2. Perceived Value in Using Analogies (Value in Using, items 1, 9, 16 and 21)

3. Future Intent to Use Analogies (Future Intent, items 2, 8, and 15)

4. Perceived Value in Students Creating Own Analogies (Students Creating, items 4, 11, 18 and 22)

5. Knowledge About Analogies (Analogy Knowledge, items 5, 12, and 19)

6. Perceived Knowledge in Science (Science Knowledge, items 7, 14 and 20)

7. Recognition of Use of Analogies (Analogy Awareness, items 6, 13, and 23)

Reliability

Reliabilities for the main part of the instrument and its subsections are presented in Table 1. The overall reliability of the Likert items is 0.90 suggesting that the instrument is reliable for this initial use. The items in the variable for knowledge of analogies have a very low reliability. The other six variables have a respectable level of reliability for this exploratory study.

Table 1

*Reliabilities for Likert Items and Variables Used in Study*

<table>
<thead>
<tr>
<th>Instrument/section</th>
<th>No. Items</th>
<th>n=</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>23</td>
<td>136</td>
<td>0.90</td>
</tr>
<tr>
<td>Posttest</td>
<td>23</td>
<td>145</td>
<td>0.92</td>
</tr>
<tr>
<td>Efficacy for Using</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>3</td>
<td>141</td>
<td>0.82</td>
</tr>
<tr>
<td>Posttest</td>
<td>3</td>
<td>147</td>
<td>0.77</td>
</tr>
<tr>
<td>Value in Using</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>4</td>
<td>142</td>
<td>0.71</td>
</tr>
<tr>
<td>Posttest</td>
<td>4</td>
<td>147</td>
<td>0.76</td>
</tr>
<tr>
<td>Future Intent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>4</td>
<td>139</td>
<td>0.72</td>
</tr>
<tr>
<td>Posttest</td>
<td>4</td>
<td>146</td>
<td>0.84</td>
</tr>
<tr>
<td>Students Creating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>3</td>
<td>142</td>
<td>0.90</td>
</tr>
<tr>
<td>Variables</td>
<td>Pretest</td>
<td>Posttest</td>
<td>Within-Subjects</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------</td>
<td>---------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>1. Efficacy for Using</td>
<td>3.40 (0.82)</td>
<td>4.11 (0.67)</td>
<td>96.74 &lt;.001</td>
</tr>
<tr>
<td>2. Value in Using</td>
<td>3.94 (0.51)</td>
<td>4.13 (0.60)</td>
<td>72.03 &lt;.001</td>
</tr>
<tr>
<td>3. Future Intent</td>
<td>4.13 (0.60)</td>
<td>4.44 (0.52)</td>
<td>57.07 &lt;.001</td>
</tr>
<tr>
<td>4. Students Creating</td>
<td>3.94 (0.52)</td>
<td>4.25 (0.59)</td>
<td>61.67 &lt;.001</td>
</tr>
<tr>
<td>5. Analogy Knowledge</td>
<td>3.22 (0.44)</td>
<td>3.34 (0.49)</td>
<td>78.14 &lt;.001</td>
</tr>
<tr>
<td>6. Science Knowledge</td>
<td>3.31 (0.86)</td>
<td>3.84 (0.68)</td>
<td>11.71 =.001</td>
</tr>
<tr>
<td>7. Analogy Awareness</td>
<td>4.08 (0.56)</td>
<td>4.31 (0.52)</td>
<td>25.66 &lt;.001</td>
</tr>
</tbody>
</table>

Results

This section will mainly explore the seven intended variables in the instrument. A repeated measures analysis was used because the instrument was used in a pretest-posttest methodology.

Multivariate tests indicated significant differences at the p<0.001 level for Wilk’s Lambda analyses of between subject effects (F=2375.56) and within subject effects (F=18.35). Table Two presents the pretest and posttest means and standard deviations and significance levels for the repeated measures univariate analyses.

Table 2

*Means and Standard Deviations of Major Variables*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pretest</th>
<th>Posttest</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Efficacy for Using</td>
<td>3.40 (0.82)</td>
<td>4.11 (0.67)</td>
<td>96.74</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>2. Value in Using</td>
<td>3.94 (0.51)</td>
<td>4.13 (0.60)</td>
<td>72.03</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>3. Future Intent</td>
<td>4.13 (0.60)</td>
<td>4.44 (0.52)</td>
<td>57.07</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4. Students Creating</td>
<td>3.94 (0.52)</td>
<td>4.25 (0.59)</td>
<td>61.67</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>5. Analogy Knowledge</td>
<td>3.22 (0.44)</td>
<td>3.34 (0.49)</td>
<td>78.14</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>6. Science Knowledge</td>
<td>3.31 (0.86)</td>
<td>3.84 (0.68)</td>
<td>11.71</td>
<td>=.001</td>
</tr>
<tr>
<td>7. Analogy Awareness</td>
<td>4.08 (0.56)</td>
<td>4.31 (0.52)</td>
<td>25.66</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Elementary versus Secondary Education Majors
Subsequent repeated measures analyses explored the interaction of teacher education program (elementary education majors versus secondary education majors) and gender on pretest posttest scores. These findings are presented in Table 3.
An examination of the above table indicates that there are significant interactions between teacher education program level and three of the seven variables (these are in bold in Table 3). There are no significant interactions by gender or by program level and gender. Table 4 presents the pretest posttest means by teacher education program level.
Table 4

Means for Significant Interactions of Program Level and Pre-Posttest Scores

<table>
<thead>
<tr>
<th>Level</th>
<th>Pretest Efficacy</th>
<th>Posttest Efficacy</th>
<th>Pretest Science</th>
<th>Posttest Science</th>
<th>Pretest Aware</th>
<th>Posttest Aware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary</td>
<td>Mean</td>
<td>3.13</td>
<td>3.99</td>
<td>3.00</td>
<td>3.61</td>
<td>3.96</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>112</td>
<td>105</td>
<td>112</td>
<td>105</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>.66</td>
<td>.71</td>
<td>.63</td>
<td>.60</td>
<td>.53</td>
</tr>
<tr>
<td>Secondary</td>
<td>Mean</td>
<td>4.37</td>
<td>4.39</td>
<td>4.49</td>
<td>4.40</td>
<td>4.52</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>30</td>
<td>43</td>
<td>30</td>
<td>43</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>.59</td>
<td>.45</td>
<td>.53</td>
<td>.54</td>
<td>.44</td>
</tr>
<tr>
<td>Total</td>
<td>Mean</td>
<td>3.40</td>
<td>4.10</td>
<td>3.31</td>
<td>3.84</td>
<td>4.08</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>142</td>
<td>148</td>
<td>142</td>
<td>148</td>
<td>142</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>.82</td>
<td>.67</td>
<td>.86</td>
<td>.68</td>
<td>.56</td>
</tr>
</tbody>
</table>

An analysis of the means indicates the nature of the interaction. The secondary education majors’ mean started off higher and had a small increase or decrease at the posttest. The elementary education majors’ pretest mean was considerably below the secondary education major’s pretest mean. At the posttest, the elementary education majors’ means showed significant increases.

The Generative Analogy Experience

Approximately half of the classes had students conduct a hands-on activity where the goal was to create and then modify or create a new analogy to help explain their experiences. The students were informed that the purpose of their analogies was not to explain something to somebody else but to help them to personally understand the phenomena. The effect of this factor was also explored through the repeated measure analysis. Table 5 presents the results of this analysis.
Table 5

*Tests for Interactions of Generative Analogy Experience and Program Level on Pre-Posttest Scores*

<table>
<thead>
<tr>
<th>Interactions</th>
<th>Measure</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-post Scores and Generative Analogy Experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficacy for Using</td>
<td>2.128</td>
<td>1</td>
<td>2.128</td>
<td>7.642</td>
<td><strong>.007</strong></td>
<td></td>
</tr>
<tr>
<td>Value in Using</td>
<td>.895</td>
<td>1</td>
<td>.895</td>
<td>10.938</td>
<td><strong>.001</strong></td>
<td></td>
</tr>
<tr>
<td>Future Intent</td>
<td>1.473</td>
<td>1</td>
<td>1.473</td>
<td>15.301</td>
<td><strong>.000</strong></td>
<td></td>
</tr>
<tr>
<td>Students Creating</td>
<td>.183</td>
<td>1</td>
<td>.183</td>
<td>1.950</td>
<td>.165</td>
<td></td>
</tr>
<tr>
<td>Analogy Knowledge</td>
<td>.125</td>
<td>1</td>
<td>.125</td>
<td>1.254</td>
<td>.265</td>
<td></td>
</tr>
<tr>
<td>Analogy Awareness</td>
<td>.003</td>
<td>1</td>
<td>.003</td>
<td>.029</td>
<td>.866</td>
<td></td>
</tr>
</tbody>
</table>

Three of these interactions are significant. Table 6 presents the means for the variables with significant interactions. The pretest means for the treatment group and the control group are similar. However, on the posttest, the group that had the generative analogy experience had large increases in the posttest scores, while the control group’s scores remained relatively constant.
This same factorial repeated measures analysis explored interactions between exposure to the generative analogy experience, program level (elementary and secondary), and the pretest posttest scores. All of these interactions were insignificant with the exception of the scores on the students creating analogies variable (p < 0.001).

Part Two of Survey

There was an open-ended response on the survey that prompted students to write an example of an analogy. The data was initially coded as a zero if nothing was written or responses were admissions of not knowing (for example, “I have no idea.”), as one if they attempted to answer but it was judged not to be an analogy, and a two if they wrote an analogy. For this analysis the data was collapsed into two categories: zero for no analogy and one for successful analogy. The means and paired sample T-test are presented in Table 7.
Table 7

Paired T-Test for Writing an Analogy Assessment

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>T</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>42</td>
<td>0.50</td>
<td>0.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>42</td>
<td>0.95</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

T-test Statistics 4.946 <.001

Reflection on the Semester

There was one item on the posttest that was not on the pretest. This item was number 24, “Because of this course, I learned a lot about using analogies in science teaching.” All of the students answering this question either gave it a 4 (agree) or 5 (strongly agree). The mean is 4.51 and the standard deviation is 0.51. There were no significant differences between elementary and secondary education majors.

Correlations

A two-tailed analysis of Pearson correlation coefficients was conducted of pretest variables. The correlations greater than 0.60 are reported in Table 8.

Table 8

Pretest Correlations of Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable</th>
<th>Strength</th>
<th>p=</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value in Using</td>
<td>Future Intent</td>
<td>.750</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Students Creating</td>
<td>Value in Using</td>
<td>.712</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Students Creating</td>
<td>Future Intent</td>
<td>.681</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Students Creating</td>
<td>Analogy Awareness</td>
<td>.668</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Science Knowledge</td>
<td>Efficacy for Using</td>
<td>.661</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
These correlations suggest a strong relationship between the value preservice teachers see in analogies and their future intent to use analogies. Further, the value seen in students creating their own analogies is strongly related to (a) the value they see in teachers using analogies, and moderately related to (b) their awareness of analogies and (c) their future intent to use analogies. The perceived ability to use analogies in science teaching is related to their perceived knowledge of science.

**Conclusion**

The Analogies in Science Teaching instrument served a useful purpose in the first stage of a four-university study on the use of analogies in preservice elementary and secondary teacher education programs.

The instrument and most of the variables had satisfactory reliability scores. The variable on knowledge of analogies had a very low reliability and this variable and its items need to be reevaluated.

The instrument did suggest there were successes in helping preservice teachers learn about analogies. There were some differences between elementary and secondary students. The secondary education students had higher pretest scores on the variables than did the elementary education students. The elementary education students had larger increases in the posttest scores. Future efforts may need to better differentiate elementary and secondary education students.

**Appendix 1: Analogies in Science Teaching Pretest**
Analogies in Science Teaching (Pretest)

This survey will be used at the beginning and end of our course to help determine your thoughts about using analogies in science teaching. You responses will be anonymous. We ask that you write the name of your favorite pet on the top of the survey. Then, will you do the survey at the end of the semester please write the same pet's name. This will allow us to determine if your responses have changed. For each item, please circle one of the following responses.

Name of my favorite pet ______________________

SA = STRONGLY AGREE
A = AGREE
UN = UNCERTAIN
D = DISAGREE
SD = STRONGLY DISAGREE

1. Science learning is enhanced when the teacher is good at presenting analogies.

2. I will use analogies frequently in my future science teaching.

3. I am comfortable using analogies in my science teaching.

4. Students could learn a lot from making their own analogies.

5. Scientists use analogies to help them understand aspects of the natural world.

6. I recall using an analogy to explain or describe something.

7. I am confident in what I know about science.

8. In my future classroom, I want to make sure I use analogies.

9. It is a good idea for teacher support materials to point out science analogies.

10. I don't know how to use analogies in teaching science.

11. I will ask my future students to construct their own analogies.

12. An analogy can perfectly describe another entity.

13. I have experienced an analogy as a helpful tool for understanding something.

14. I think I know enough science to be a good science teacher.

15. I don't plan on using analogies in my future teaching.
SA = STRONGLY AGREE; A = AGREE; UN= UNCERTAIN; D = DISAGREE;
SD = STRONGLY DISAGREE

16. Developing or finding appropriate analogies is a good use of instructional planning time.     SD D UN A SA
17. I understand how to use analogies to teach science concepts.                              SD D UN A SA
18. I don’t think students would benefit greatly from making their own analogies.            SD D UN A SA
19. Analogies frequently lead to misconceptions.                                            SD D UN A SA
20. My knowledge of science is better than the average person.                             SD D UN A SA
21. Analogies are an essential tool for teaching science concepts                            SD D UN A SA
22. It is a good use of class time to ask students to create their own analogies.           SD D UN A SA
23. When I observe or participate in a lesson, I am aware when analogies are used.          SD D UN A SA

Please answer the following questions.

A. Number of college science courses you have taken _______    Sex: Male  Female
B. I intend to teach at this level:  elementary  middle school  high school

C. For the level I plan on teaching, please rate your confidence to teach each of the following areas of science (1= not confident, 4 = quite confident):
   Life Science    1  2  3  4  5
   Physics         1  2  3  4  5
   Chemistry       1  2  3  4  5
   Earth & Space Science 1  2  3  4  5

D. The optimal mix in your future science classroom (Please circle one):
   Teacher presents concepts 1  2  3  4  Students discover concepts

E. Please write an example of an analogy in the space below:

The End: Thanks for your time.
SCIENCE EDUCATION COMMUNITY COLLABORATIVE: A LESSON IN PROFESSIONAL DEVELOPMENT

Amy M. Robertson, University of Texas at Austin

In this study, multiple stakeholders in science education, including formal educators at the elementary level, university scientists, informal educators, and an educational researcher, came together for the purpose of creating educational field trip experiences. Although the primary goal of the collaboration was to create field trip curricula, what resulted was much more powerful than any of us had expected. The interactions with others in the science education community produced an unparalleled professional development experience for everyone involved. The results of this study give a detailed account of the participants’ perspectives and experiences throughout the collaborative process. It describes the unique professional development benefits that each collaborator received from working closely within a science education community.

Theoretical Background

In successful collaborations, the goals of the stakeholders are brought together to form a shared vision by linking their individual knowledge bases (Mattessich, Murray-Close, & Monsey, 2001). A high priority is placed on incorporating multiple perspectives in the collaboration. The knowledge is located in not just one of the individual stakeholders, but in the collaboration of them all (Cochran-Smith, 1991). All of the sets of knowledge are essential for a full understanding of the situation. As the collection of knowledge is brought together to form a shared vision, the individuals in the collaboration are learning and reconstructing their own conceptions. This view of collaboration has its basis in the theoretical underpinnings of both constructivism and sociocultural theory. The participants in the collaboration actively construct and alter their conceptions about teaching and learning as they create and communicate together. As the partners collaborate, the dialogue about joint projects enables everyone to benefit from the socially constructed knowledge base. It is that knowledge base that provides a foundation for effective collaborations (Grisham, Bergeron, Brink, Farnan, Lenski, & Meyerson, 1999). And it is the collective knowledge base that is of particular interest in this study’s collaboration.
The Benefits of Collaboration

Research provides evidence that the participants in educational collaborations receive many professional and personal benefits as a result of collaborating. One of the few in-depth studies found in the literature describing collaborations connecting all of the stakeholders in science education is by Barufaldi and Reinhartz (2001). It contained a description of a statewide collaboration involving a professional development program for science teachers and lists several benefits that each collaborating organization gained. There was not much description about how the collaborative process impacted each individual in the collaboration, though.

However, there is much documentation and research on the benefits of individual partnerships between formal and informal education, between formal education and scientists, and those involving education researchers. One particularly successful and extensive collaboration is the Science and Health Education Partnership (SEP) between the University of California, San Francisco and the San Francisco School District (Clark, 1996). Many of the individual and long-term scientist/teacher partnerships within the SEP produced benefits such as increased teacher interest in science and a deeper knowledge of teaching and learning for the scientists (Clark, 1996). In addition, one education researcher/formal educator type of collaboration that is widely supported is the professional development school (PDS) movement. The goal of PDSs is to move toward an improved concept of preservice teacher education with simultaneous renewal of schools and the education of educators through the connecting of the school and university cultures (Goodlad, 1993). Through this collaboration process, classroom practices and teacher preparation change and evolve (Grisham et al., 1999). A couple of studies investigating formal and informal education collaborations also illustrated many professional benefits including a greater understanding of effective teaching practices by both the formal and the informal educators (Bainer, Cantrell, & Barron, 2000;
Bainer & Williams, 1996). As demonstrated by these examples, collaboration can be an
effective professional development tool.

Methodology

Research Design

In order to gain a holistic perspective of the collaboration, a qualitative case study
design was implemented. The coming together of these different sides of science education
provided a unique opportunity to explore the issues and experiences that emerged as such a
partnership was formed and developed. Merriam (1988) states that a case study is appropriate
when one wants to develop a better understanding of the dynamics and processes of such a
program in order to improve practice.

The general design of this study was also heavily influenced by action research. The
goal of action research is for professional researchers and local stakeholders to collaboratively
seek and enact solutions to real-life problems of major importance to the stakeholders within a
given context (Greenwood & Levin, 2000). Action research consists of a continuous cycle of
self-reflection that involves planning, acting and observing, reflecting, and replanning (Carr &
Kemmis, 1986; Kemmis & McTaggart, 2000). Success is determined by whether or not the
participants have a strong sense of understanding and development in their practices (Kemmis
& McTaggart, 2000). One of the major goals of this study was to improve the practice of
designing field trip experiences collaboratively between local stakeholders in formal
education, informal education, and educational research. With each new field trip, the
collaborative partners in this case study undertook a cycle of planning, acting and observing,
reflecting, and replanning as suggested by action research. The members of the collaboration
intentionally planned for this cycle of reflection about the field trips to occur during meetings.
A similar cycle of reflection on the general collaborative process also occurred, but in a more
spontaneous manner.
Setting and Participants
The field trip site and the location of most of the collaborative events is a multi-purpose site that is built upon partnerships. It is used as a biosolids reuse facility for the city, is home to an environmental partnership of several nonprofit organizations, and has a research center for the local universities. This collection of associations provided many different human resources to draw upon including city workers, naturalists, university students and professors, and other community members. In addition, the site contains a rich array of ecological resources that made it an attractive site for an environmental field trip program.

The elementary school is located near the field trip site, so they are both members of the same community. It is a rural school in a predominantly low SES area in which 63% of the students are considered economically disadvantaged (Texas Education Agency, 2001). At the time, the school did not have a very extensive science program for the fourth and fifth graders and no science laboratory.

The primary participants in the collaboration include two elementary school teachers who volunteered to act as representatives for all of the fourth and fifth grade teachers at their school, two scientists from local universities, an informal educator from an environmental education site, and the researcher acting as a participant observer. In addition, there are several other secondary stakeholders such as the principal, other teachers, and volunteer field trip guides.

Data Collection and Analysis
The data collection period spanned from November 2000 until May 2001. The data was collected by means of participant-observation of planning meetings, semi-structured interviews with each major stakeholder in the collaboration, and written document review. The sources of data include both the participants directly involved in the collaboration as well as the secondary stakeholders. The primary partners in the collaboration were interviewed 4 times, once at the beginning of the research period and after each of the three field trips.
Multiple interviews demonstrated how their perspectives evolved over the course of the collaboration. Secondary participants in the collaboration were interviewed twice, once near the beginning of the study and once at the end. In addition, documents, such as student writings, vitas, memos, and the researcher’s journal were investigated. The use of multiple data sources and types helped establish the most complete and trustworthy description of the research findings.

Data analysis was done simultaneously with data collection and continued after data collection was completed. I drew from the general methodology of grounded theory in order to develop theory from the data. Open coding was used. The codes were then categorized and linked together to form theoretical models. The constant comparative method was used to examine and reexamine the data in order to develop the categories and theory. The issue of trustworthiness was addressed by means of triangulation, member-checking, and peer review.

**Results and Discussions**

**Description of the Collaboration**

**Background of the Collaboration**

This collaboration was formed in order to create educational field trip experiences. The backgrounds of these collaborators as well as how they became a part of the collaboration extensively affected their goals, actions, and motivations. The two teachers from the elementary school acted as representative teachers for their grade levels, one from fourth grade and one from fifth grade. Both of these classroom teachers had a general interest in science. The fifth grade teacher was familiar with the field trip site as a bird watching site and contacted the site’s coordinator to discuss their interest in bringing their students on a field trip. The site’s coordinator, an informal educator and naturalist who has a broad knowledge of the site and its ecological makeup, was interested in expanding the facility’s uses and was eager to work with the teachers to plan the trips. His main goal for the program was to give
the students experiences that will engage them and interest them in science. He wanted it to be useful for the teachers, but he wanted to keep it informal. The two scientists had been involved in different research activities at the field trip site before and knew it and the people that worked there well. The main reasons they joined the collaboration was because of their love of the site and a desire to help expand the science content of the field trips. With my research interest in helping connect the field trips to the classroom curriculum, I was also added to the group.

General Account of the Collaborative Events
The collaborators met at least once before and after each of the three field trips. Anyone involved in the collaboration was invited, but not all of the teachers, administrators, and mentors came to the meetings. However, the two representative teachers, the informal educator, the two scientists, a few mentors, and I came to nearly all of the planning meetings. The goal was to have at least these core members of the collaboration present at the meetings, and it was only on rare occasion that anyone was absent. During the planning meetings we discussed the topics that we wanted to cover, the field trip activities that would be appropriate, and possible classroom curricula. Often one planning meeting for each field trip was not enough; so further planning was done in other meetings, by phone, or email. During follow-up meetings, we discussed how the field trip functioned, and where improvements might be needed. The meetings were held in the evenings after the teachers got out of school. The meetings were casual and friendly in nature. We sat in a conference room located at the field trip site around a large table, eating snacks that one of us had brought. The meetings were mostly business because we had so much planning that needed to get done. During the meetings the collaborators discussed field trip details ranging from the mundane logistics (e.g., dates and times of the field trips) to more substantive issues such as curricular content. No one officially led the meetings, and they were not very structured. But the coordinator of the informal site would try to keep us on task when we strayed off topic.
The three field trips were held in November 2000, late February/early March 2001, and in May of 2001. The teachers, the scientists, and I all participated as mentors, or field trip guides, during the field trips. Additional mentors included volunteers from community groups such as the Audubon Society and other naturalist groups. All of the volunteer mentors were educated before each field trip. The field trip training days were each half-a-day on a Saturday. The mentors were taught the science content that would be covered during the field trip. They also took a run-through of the field trip day, visiting the locations that they would take the students. In addition, the mentors were informed of the backgrounds of the students and the best way to guide their learning (e.g., by asking questions and finding what interested each student). Discipline issues were also discussed. Before and after each of the field trips, the teachers were responsible for presenting pre- and post-field trips activities in the classroom. Also, before each of the field trips, the scientists introduced the students to the upcoming field trip topic with what we called a “dog and pony show.” The scientists went to each classroom and informed the students about what they could expect to see and do on the next field trip and gave them some background knowledge to work from.

Roles of the Collaborators

Though I have labeled the participants in the collaboration the informal educator, the scientists, the classroom teachers, and the education researcher, this is for mere ease of identification. None of us fell under just one of these labels. In fact, there were many tasks to which all of us contributed. For instance, each of us acted as a mentor during the field trips and all of us had input into the field trip curriculum and organization. Throughout the collaboration, we all crossed the boundaries of these labels and took on several roles and different responsibilities. From the onset of the collaboration we did not have defined roles.

The collaborators appreciated the fact that we were able to choose our own roles and let them evolve over the course of the year. One reason that most of the participants wanted undefined roles was because they felt it would allow everyone’s input to be heard about all
aspects of the field trips. In a way, they felt it kept the lines of communication open. The
fourth grade teacher stressed the need for less rigid roles,

I like it because then the people feel free to speak up on any issue. I think if I
felt like [one of the scientists] is really perhaps going to be in charge of
curriculum or I am simply going to be logistics or whatever, then we wouldn’t
get the ideas in every way. I really like it when people feel free to speak. I
think it is good.
The fifth grade teacher also commented that she also prefers to work that way because she has
a “hard time being stuck in a slot” and valued the fact that “everybody has the opportunity to
contribute if they want to.” One of the scientists mentioned that she appreciated having
undefined roles for much the same reason. She said,

I like that. I like to think of us all on the same playing field…all with equal
input. That works if we all listen very carefully to the other people’s
input…The fact that we didn’t have any roles maybe means that we stay more
open to helping each other.
Because everyone had a voice in every aspect of the collaboration, this meant that no single
person had complete authority over an aspect of the collaboration or resulting field trips.
Whenever possible, we tried to create any final decisions from a compromise of perspectives.
In the end, everyone agreed that the collaboration was successful because of the many
viewpoints that went into creating the field trips. Not only were the end products of the
collaboration (i.e., the educational experiences) improved because of the different
perspectives that were incorporated, but also this was what helped make this an effective
professional development experience. Each of us learned more because we were involved in
all aspects of the planning.

Developing the Educational Experiences and a Shared Vision
Developing a shared vision is an important factor in any successful collaboration
(Barufaldi, 2000). Participants in a collaboration must have the same expectations, strategies,
and goals (Barufaldi, 2000; Spector, Strong, & King, 1995). In this case, the process of
creating a shared vision of the educational experiences is what transformed the collaboration
into a professional development opportunity.
In general, the main goal of this collaboration was to create a beneficial educational experience for the students. This vague main goal was shared by all of the participants at the start of the collaboration. However, the collaborators’ original visions of what a “beneficial educational experience” looks like differed to some degree, as did our visions of how to achieve this goal. These differences were mainly due to diverse backgrounds and priorities and distinct ideas relating to the participants’ definitions of successful field trip experiences and their definitions of learning.

The informal educator, considered himself the “loosest” when it comes to the definition of education and what “counts” as learning. He stated that he does not “have a fixed image of what counts as education in this program beyond getting the kids outside and getting them engaged.” He added, “I do not have huge goals for science for these kids. I want them to come away with an excitement for observation and engagement. All of those are the foundation of what would make someone want to do science.” He felt that much of the tension found within the program lies in the participants’ different definitions of teaching science. “Teach them Science…with the big S or to have science as a part of an experience that they have.” In making the field trips successful, the factors that he seemed most concerned about had to do with the site and the logistics of the trip. These included safety, low student to mentor ratios, and place-based appreciation of the site. He also emphasized the virtues of mentoring, which was one of his most important personal goals for the program. This involved learning from each other and creating social bonds between all involved, including the students, teachers, and mentors.

The teachers appeared to have their minds on all aspects of the field trips. Due to their past experience with field trips, they were especially concerned with the logistics of the trip. Also, the teachers seemed to be the most worried about making the learning experience relevant to the students’ lives and backgrounds. Most of the teachers desired a learning
experience that met their district objectives. However, some of the teachers did not seem to have learning as a main goal for the field trip.

The scientists were not originally as concerned about the role of logistics in a successful field trip, and were mainly worried about affective and educational goals of the trip. However, they soon realized the importance of having all the organizational issues to be in order. The scientists had somewhat differing views on learning, largely due to the fact that they both learned in different ways. They both look at science and nature in a holistic manner, but one of the scientists finds it easiest to store information in her mind by naming and categorizing organisms. It is not as vital for the other scientists to have a name for an organism. This difference in their learning styles would end up playing a large role in what content they believed should be included in the curricula.

My main goal was to make the field trips flow with the classroom curriculum. This is due to my reading of educational research that professes the virtues of having connected and continuous learning experiences. I believe that learning can take many forms, some of which cannot be adequately expressed with content-focused tests. To me, some of the most important learning is an affective increase in interest and appreciation for science. So, I wanted to focus on making the learning interesting and relevant for the children. However, I did worry about the field trip objectives tying into district science objectives only because I knew the pressure the school was under not to “waste time.” I did not originally place as much emphasis on the logistics of the field trips. This was probably because I had never had to coordinate hundreds of students and many mentors on field trips before.

So even though each of us had a different emphasis in mind for the field trips, we all agreed that it should provide a beneficial educational experience for the students. Despite our different priorities, cultures, teaching and learning styles, and pressures, we did come to a middle ground. The participants gained understanding, learned, and changed in order to begin
to share a more unified vision of how the educational experiences should be structured as well as how the collaboration could best function to accomplish this task.

**Development Through Communication and Understanding Other Perspectives**

A combination of communication and listening in order to really understand others’ viewpoints helped most in synchronizing our intentions. One example of this occurred when the collaborators were deciding on the level of the content that was to be incorporated into the field trips and surrounding classroom curricula. Everyone agreed that the students should learn something on the field trips, but the group members of the collaboration disagreed on what that something should be. In most cases, the scientists tended to push for higher content level than the teachers thought was suitable. The informal educator and I were usually somewhere in the middle of the continuum.

At first, the scientists believed that they should “challenge the ones that might be most interested and drag the others along.” The informal educator suggested that because they are university professors, their expectations of what the students need to know are higher. The scientists struggled over “how much of the memorization, how much of the jargon, how much of the vocabulary they [the students] need in order to go out in the field and actually observe and be able to understand what they are observing.” One scientist emphasized that she did not want “to assume for them [the students] that they cannot learn.”

In the beginning, most of the teachers’ suggestions about the content level came in the form of stories about how low their students were, rather than direct complaints about the content being too high. This was probably out of politeness because the group was not as comfortable with each other at first. While the collaborators’ thoughts were not originally openly stated to the rest of the group, they did individually discuss their feelings with me in confidence, as the researcher. The teachers tended to agree that the first field trip and surrounding classroom curriculum were often too complex for most of the students. Some of the teachers protested that some aspects were too “abstract for the kids,” that we “tried to
cover too much,” and that the scientists “expected a little more than they [the students] were capable of.” Most of the complaints were about the inclusion of a taxonomy lesson and the scientific names of the insects.

After the first field trip, we all did agree that the content was too difficult for the students at times. By the second and the third field trips, the topic of content level was discussed at length. We realized that communication was key in working out our differences. This helped open the dialogue about expectations related to the content level. So, in the next meeting the teachers more openly expressed their perspectives on the content level. In support of their perspectives, the informal educator encouraged the others, “Are you hearing these classroom teachers say we need to keep it more limited, we need to keep it more focused.” Appreciatively, the fourth grade teacher noted that he “has always been extremely respectful to what it is like in the trenches in here.” She also valued the way that one of the scientists especially paid attention to what they were saying. She commented, “she actually kind of listens to me, a lowly school teacher…you know, saying what these kids are like from this age group and this culture. And she has been reinforcing and receptive and encouraging for me to share suggestions and made me feel like I was not overstepping my bounds. She made me feel okay about it.” In return, the scientists appreciated the fact that the teachers expressed their concerns. One scientist said that the fourth grade teachers especially had been “forthright in some of the things she has said, and that has been really valuable to me. She is outspoken. I think she does it to be constructive, and I like that.”

After the second planning meeting, the teachers felt that “everybody got heard” and that “we had made it [the curriculum] better.” After these discussions, some of the collaborators’ viewpoints regarding content level did begin to incorporate the ideas of the other collaborators. One of the scientists was particularly trying to learn from the teachers what was appropriate for the students. She began to discuss topics using many different
methods of teaching such as demonstrating with words, pictures, analogies, both visually and verbally. In addition, although they still did not want to frustrate the students, the teachers did begin to realize the importance of having high expectations. One of the other fourth grade teachers mentioned that it was good for the students “to be challenged and realize there is more out there to learn.” Some of the teachers were surprised to see what their students could learn. This was the case for one exercise that required the students to categorize different insects. The teacher explained,

I was worried ahead of time that it was going to be too difficult for the students to be able to distinguish between each one of the categories, but it wasn’t. So the kids actually put them where they belonged. I thought it was above the kids’ level, but it turned out that it wasn’t.

Through communication and experience with each other in the collaboration, each of us learned at least some of the virtues of the others’ perspectives. Small, yet significant viewpoint changes were made. The teachers learned to take their students’ learning to the next level. They realized that the students could handle more complex concepts than just learning some science facts. They realized the students could use their new information if given the chance. The scientists learned how to better teach to different learning styles and learning levels. Although all of the communication back and forth took a lot of time, through these interactions, we all learned that each collaborator’s perspective is important in creating the best curriculum possible.

Development Through Community Building
In addition to better communication, ownership and dedication to make the field trips better and a sense of community which grew over time also contributed to a more shared vision and better understanding of one another. An example of this was observed when the other fourth and fifth grade teachers were inconsistently using the classroom curriculum.

All of the primary participants in the collaboration agreed that it was a good idea to have pre- and post-field trip activities for the classroom. So, we decided to put suggested curricular activities in a notebook for all of the students. We put forth great effort to make the
curriculum useful for all the teachers. The collection of classroom activities included science activities as well as many lessons in the other subject areas. The principal had explained to us that, “what has happened traditionally is that the subjects that were tested on the state accountability tests is what we put the most emphasis on. You might do science every other week.” Because the school, and thus the teachers, put a lot of stress on the state tested subjects of mathematics and reading, we included many learning activities that were directed towards these objectives while also covering the relevant science content. For instance we would include reading passages and questions that were about relevant science topics. We were hoping that by doing this, the teachers would realize they did not have to take away too much time to teach science, since they were already under great pressure with the other subject areas.

Despite the effort and thought that we put into the curriculum for the first field trip, some of the teachers, especially in the fifth grade, did very few of the activities. It was obvious that we needed to do more to educate, encourage, and excite the teachers about the program. They needed more direct information and ownership to buy into the program and really have their heart into it. This made me realize that you cannot just impose curriculum changes on to teachers if they do not buy into it. You have to involve them and educate them. They have to understand why it is important or they will just do whatever they want (or whatever is easier). We made it a goal to help motivate the other teachers to get more involved with the second field trip. The fifth grade teacher also suggested, “The more organized and the more prepared we are, the better. That is where the teacher needs to not stress out.” So we gave ourselves more time, and we brought the curriculum to the teachers earlier for the second field trip because there were some teachers who liked to plan months in advance. In addition, before the second field trip, we tried to increase the amount of communication with the other teachers and encouraged their input more. Once they became
more knowledgeable about the program and of the curriculum notebooks, experienced the
field trips, and became more familiar with the field trip site, they seemed to gain more
ownership in the program and started participating more. Furthermore, through an increase in
communication, there was a greater understanding and respect between the other teachers and
the rest of the collaborators. As one of the scientists stated, “we all knew each other and
knew a little bit more about each other and knew how each of us worked…They knew us
better, we knew them better.”

On the second field trip, one of the biggest changes was seen in the teachers’ attitudes
and participation. More of the teachers and mentors helped in developing the classroom
curriculum. The representative teachers in the collaboration, as well as some of the other
teachers provided several activities for the curriculum. The teachers’ ownership and
involvement in the program increased throughout the year. As the fifth grade teacher stated
after the last field trip, “the teachers have become more and more enthusiastic about this
partnership!” She added, “I am very, very pleased. I like the way the teachers have gotten
more into it. They have created more on their own…added to it. Even some of the more
reluctant ones have.” Because of improved communication and experience with the
collaboration, the other teachers’ motivation and dedication towards the program increased, as
did their involvement and support, causing us to have more of a shared vision about the
classroom curriculum. Indeed, this dedication resulted in more use and contribution to the
classroom curriculum.

The End Product
Our individual visions for the field trips evolved over the year while becoming more
similar to one another. The fourth grade teacher explained that the field trips have “just
evolved. They have grown and grown and grown.” When asked what she thought made the
field trips improve she replied, “It is just really refined and worked out and planned here....We
have so much input and are learning so much from each other and previous experiences.”
Although we probably did not each possess the *exact* same idea of how to structure the field trip experiences, our visions were much more shared by the end of the year. The very vague vision of a “beneficial educational experience” that we began the collaboration with became much more focused and clear by the end of the year. Our shared vision of what the educational experience should look like came to include having more accurate, higher level content taught to different learning styles, using connected formal and informal education experiences, which were integrated into different subject areas. As a group, we strived for experiences which were structured enough to keep the kids behavior in line and generally on topic, but open enough to allow for each student to explore and discover their own interests. Although the resulting field trip curriculum did not look exactly like what any of us had originally envisioned, we all agreed that the final product benefited the most students possible. The field trip was flexible enough to let the students be creative, but gave just the right amount of focus. There were complex and more basic concepts from which to select. The students were engaged and on task and often surprised the adults by what they had learned. Everyone seemed pleased with the end product.

**Benefits of the Collaborators**
The process of collaboration, and specifically creating a shared vision, resulted in a greatly improved educational experience. The field trips were fully integrated into the classroom curriculum, and the students gained cognitively, affectively, and socially from the experience. But there were also many unintentional personal and professional benefits that each of the collaborators experienced. One of the defining characteristics of a collaboration is that it is mutually beneficial to the participants (Winer & Ray, 1994). Whether or not the participants benefited from the collaboration helps explain their actions and motivations throughout the year and has implications on the level of commitment the individuals will exhibit in the future. Table 1 contains a brief summary of the collaborators’ benefits.

Table 1
## Benefits of the Collaborators

<table>
<thead>
<tr>
<th>Collaborator</th>
<th>Learning</th>
<th>Improved Teaching</th>
<th>Enjoyment/Enthusiasm</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th Grade Teacher</td>
<td>-science content</td>
<td>-taught at a higher level</td>
<td>-motivation and renewed hope</td>
</tr>
<tr>
<td></td>
<td>- science as a system</td>
<td>-better logistics of field trips</td>
<td>about science education</td>
</tr>
<tr>
<td></td>
<td>- about collaborations</td>
<td>- higher expectations for students</td>
<td>-enjoyed creating fun ways of</td>
</tr>
<tr>
<td></td>
<td>- about good teaching practices</td>
<td>-better integration of field trips</td>
<td>learning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>into curriculum</td>
<td>-enjoyed working with the group</td>
</tr>
<tr>
<td>5th Grade Teacher</td>
<td>-science content</td>
<td>-encouraged to do more</td>
<td>-increased hope for public</td>
</tr>
<tr>
<td></td>
<td>- about collaboration</td>
<td>-motivated to try something</td>
<td>education</td>
</tr>
<tr>
<td></td>
<td>- about good teaching practices</td>
<td>different</td>
<td>-enjoyed working with the group</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-felt support from others</td>
</tr>
</tbody>
</table>

Table 1 (continued from previous page)

**Benefits of the Collaborators**
Informal Educator
- logistical aspects of field trips
- insight into own teaching ways of assessment
- challenged to find more valid assessment
- enjoyed accomplishing his goals for the site
- enjoyed working with the group

Scientist #1
- science content
- learned about different learning styles
- more about elementary school and public education
- became able to engage different types of students
- more about the site
- learned about integrating field trips into curriculum
- increased faith in collaboration
- enjoyed working with the group
- enjoyed seeing mentoring happen

Scientist #2
- about elementary education in public schools
- learned about different learning styles
- enjoyed seeing students learn

Education Researcher
- -- science content
- better able to teach to different learning styles
- about formal education
- about informal education
- enjoyed working with the group

**Classroom Teachers**

Although all the classroom teachers that were interviewed reported benefits due to the collaboration, the teachers that most directly participated in the collaboration benefited most. All of the teachers gained science content knowledge, often during the field trips right along with the students. The fourth grade teacher describes one of her learning moments during the third field trip.

I was really proud of myself because I knew some things, because you had prepared me. I recognized lamb’s quarters. And I even got to have a little question with [one of the mentors] about a plant. She had thought something was mesquite, and I guess I had grown up enough around mesquite to know it wasn’t mesquite. It was something else. That was really fun. We were learning and we were the grown-ups and the kids saw that. I had been trained a little and she had been trained a little. We could teach and learn in front of them. That is great because they see us getting excited.

The scientists helped the teachers look at science as more of a system rather than a collection of facts. The fourth grade teacher explains how the scientists taught her to take specific facts
and content areas and apply them on a larger scale: “she is reminding me to take that
information] into a bigger cycle and always take that and apply it to the big picture.”

The teachers also gained knowledge about better teaching practices. For instance, the
collaboration and resulting field trips reinforced the value of hands-on, experiential learning.
The fifth grade teacher says, “I have always been an advocate for it, but now I am totally a
firm believer.” She also realized that a low student-teacher ratio is key. She explains, “I can’t
serve the students the way they need to be served and the way that I want to serve them when
there is 20 or so in my classroom.” The teachers that primarily participated in the
collaboration learned more about the process of collaboration. The fifth grade teacher says
that she learned “that I have to be flexible, that my way isn’t the only way.” She says that it is
important to “be open to different approaches.” All of the teachers received resources in the
form of background information, handouts, and notebooks with curriculum activities. The
support from others in the collaboration also benefited the teachers. As one teacher states,
“We need a lot of help. The interest in it is very encouraging. It makes me feel good about
teaching…that we have that opportunity and partnership.” The fourth grade teacher reiterates,
“It is nice to have a reminder that there are other sources rather than just workbooks. There
are people.” She goes on to describe how the support that she received from others in the
collaboration helped her with the difficult reality of teaching fourth graders.

People are going to reinforce this with me, so I feel more supported and not
like I am barking up a tree. It is people helping me with my reality, and they
have helped a lot…Sometimes you get a little tired. You get a little…not
hopeless, but you get a little like ‘scrap this, we are just going to get to the
bare nicks and bones.’ But with all of this wonderful support I am given
renewed hope on truly effectively communicating certain things that I
probably would not attempt. That is wonderful. I am being taught that ‘yeah,
you can do this, you just need a little help, you need some resources, you need
a little support.

Over the course of the collaboration, she came to the realization that she needed the kind of
support and extra motivation that the collaboration provided.
What I like about this is that it is inspiring me to not take the easy route, write it off, or just do workbooks, or not address that area. Teachers need renewing…we need inspiration. That is what I think about when I think about myself in this. Once again, just like when I come back from a great workshop, ‘yeah, that is why I chose to do this and love this. Oh yeah, I do really like teaching.’ The fact that I need renewal and inspiration and support and resources…I need to remind myself to have that and to keep doing that. I want to be the kind of teacher that survives…I am going to find out what is healthy. And this collaboration has definitely helped me to realize that…that I want to stay on a higher plane and really that I need that.

The fifth grade teacher also expressed how the collaboration and the support structure behind it gave her a sense of encouragement about teaching.

I really had become quite discouraged with public education. And [this collaboration] has been one of the most positive things we have done this year as far as showing me that there is still some hope for public education. As long as we can have these kind of partnerships and collaborations, then maybe there is hope still.

This sense of support, in addition to the science content and the lessons learned about teaching, helped improve the formal educators’ teaching abilities. First of all, the teachers felt motivated to go further with their science teaching and really use the field trip days as learning experiences. The fourth grade teacher noted, “I think that it keeps the teachers on their toes. You know with our population, the reading, the math, and the writing are first. Social studies and science are on the backburner. This is forcing us to keep those upfront, make sure our kids are up to date in those areas.” She explained how she became more motivated to teach at a higher level and to have higher expectations for her students.

Researcher: Can you describe to me the level of preparation your kids had?
Fourth grade teacher: Birds, that is pretty rote, it is pictures to words. But with [the scientists] coming in and talking about those relationships and bigger picture ecosystems, and cycles, and herbivores, it has gotten wider. So the teaching has gotten better. Like those review sheets I just gave you. I am forced to get away from just the knowledge.
Researcher: You are talking about your teaching?
Fourth grade teacher: My teaching is getting away from the bottom of Bloom’s taxonomy and more to truly application and analysis and synthesis. It is more of the bigger picture. I am trying it out on them. I am trying to have higher expectations for them.
Researcher: Because of what [the scientists] have done? Or are you just trying to do more, or…?
Fourth grade teacher: Well, they have taught me and reminded me. It is like it is worth it because we are going to see it…It just gives me more incentive to
take it to a higher plane in an area I might not normally, because I have no reason to. This teacher also mentioned that she wrote in her self-appraisal for the principal that the collaboration helped her teaching by allowing her to integrate the field trips into the state standards and tests and other content areas while making the learning relevant. This was important because there is so much pressure to focus on the state standardized tests and the content areas that are tested.

An additional benefit that the teachers reported was a sense of enjoyment. All of the interviewed teachers mentioned that they had a good time on the field trips. The representative teachers enjoyed working with the other people in the collaboration. In an interview the fourth grade teacher affirms, “I really liked meeting you all…I have enjoyed our collaboration…I liked the adult side of it. I guess teachers, that is so often our complaint, we are with kids a lot and sometimes we want things on a higher plane. It is just nice to be around adults. I like talking about things that I am usually on my own on.” She also specifically mentioned that she took pleasure in “creating fun ways of learning.” In agreement, the fifth grade teacher states, “I am driven by trying to do something exciting and different, and these field trips meet all of that.”

**University Scientists**

As with the elementary teachers, the scientists also benefited by learning content and more about education and collaboration, and by improved teaching and a sense of enjoyment. Even though the scientists were often thought of as the “content specialists,” they learned a lot during the collaboration and resulting field trips. They learned new science content such as information on different kinds of birds or macroinvertebrates. In addition, they gained a better understanding of the material they had previously known, because they had to teach it to a different audience than they were used to. Both of the scientists gained a better understanding of public education at the elementary school level as well as the working conditions for
elementary teachers. One of the scientists describes how working in the collaboration helped her become more aware of public education in this community.

“It has been very nice to be around some kids and to have a reality check on schools and teachers and kids. I can isolate myself from all of that very easily in this academic ivory tower. That has really been good for me to understand at a community level a little bit about what is going on in a community that I am not a part of, or am not used to being a part of. I have now, in a way, become a little part of that community. The informal educator reiterates, “It has helped them to understand the school better. I think it has been really good for both of them to understand what that kind of education is like.”

During the collaboration, the scientists also gained insight on the stresses and demands put on the teachers. One of them remarked, “I have a real appreciation of the hard, unrewarding work that teachers put in....That was good for me to understand, because I didn’t understand that before.”

Moreover, the scientists learned a lot about teaching and learning. In particular, they began to better understand that people have individual differences in their optimal learning styles. After the classroom teachers discussed their students’ different individual needs with all of the collaborators, the scientists began to more consciously incorporate different ways of teaching in their lessons to the students. One of the scientists explained how she noticed improvements in her own teaching during the second field trip.

“We have progressed in addressing the needs of the different kids. That was one of my objectives for the second [field trip]...to try to understand to have kinesthetic, visual, verbal, to repeat things a number of times, to try to do all of that a little better...I felt like I was learning and I was doing a little better. She explained how this was a real challenge during the field trips and how she had learned to try to keep her mind open to different ways of approaching the learning events. She stated, “any teaching I do ever, I will be much, much more aware of how to engage everyone’s learning style.”

The scientists also learned more about field trips and how to make them more educationally useful. I provided them with information from my studies of informal education
and better ways to integrate field trips into the classroom curriculum. Both the elementary teachers and I emphasized the inclusion of some of the state objectives into the field trip curriculum. During the collaboration and three field trip experiences, we all focused on having “pre-activities and post-activities to reinforce…to prepare them to see through their own eyes the most possible when they are at [the site].….And then to reinforce what they have seen afterwards with those activities.” One of the scientists states, “It is a challenge to try to coordinate their curriculum and the [standardized state] requirements, the place-based outdoors hands-on site…that is a challenge and that is exciting. I didn’t understand…you were the one that really put a context to field days that was intriguing to me to try to improve on.”

Another way in which the scientists benefited from the collaboration was through the pleasure that they received from their participation. One of the scientists articulates,

I was delighted with the energy on the part of so many people. So I think the collaboration, in my opinion went really well. There was a real diversity from retired teachers, to teachers, to college students, to high school students. That was a real pleasure to see happen, the whole concept of mentoring really did happen. So, that is my first joy in the whole thing. She added that this experience has increased her faith in collaboration. She explains, “this doesn’t come naturally to me. I really prefer doing things by myself” however, “it has been an absolute pleasure to work with our core team….It was definitely well done. That is a tremendous relief. It showed me that collaboration can work.”

Informal Educator

Even after just the first field trip, the informal educator mentioned how he had already “learned so many things.” He discussed how he learned many pragmatic ways to improve the field trips, such as the best ways to get the groups of students around the field trip site and how to structure the field trip days. He also learned more about the people involved in the collaboration, and “of what people are good at and what they are not so good at.” This helped him direct people to do different tasks for the field trips. He also gained more insight into his
own teaching practices and beliefs about education. He had thought that a major goal in education should be to develop a consciousness in people, and he felt that this experience was an affirmation of that process. He found it very satisfying “to see the fourth and fifth graders begin to develop a consciousness of their own place in the world and of other organisms in the world, and that they live in a place as opposed to just anywhere.” He also realized that he had set up the university courses he teaches with that same goal in mind.

In addition, this experience with the students challenged him to always try to find more valid ways to assess learning. He explains, “Education is about learning and not measuring. That is why exams to me are kind of ridiculous and artificial ways of gauging learning. And we need structures that let us evaluate learning as opposed to measuring knowledge. That is the challenge for me.” He explains how he witnessed so much learning from the students, and everyone else that participated in the field trips, and that this was difficult to measure. The fact that they were able to discuss topics together was proof of their learning.

These kids, the fourth and fifth graders…what is neat to see is that they can come to me and talk about blood weed or talk about turkey vultures. Then I will talk to a professor who is talking to this other person who may know something about this…they are all talking from a common ground. He goes on to discuss how formal science education is designed to be limited, because it does not often provide opportunities for the students to explore and discuss their learning as in informal education situations such as this one. He also states, “I certainly learned the limitations of formal scientific practice in exciting these kids.”

The collaboration experience also benefited the informal educator because of the excitement and satisfaction of accomplishing his goals for the site. His mission for the site was to increase partnerships and creative programs while empowering people to make a change. He explains his pleasure in seeing this goal being realized. “To see all of those people empowered, that is the most satisfying thing to me. I have always envisioned [this site] as a
place where we can do stuff like that. And to see it actually happening is really an exciting thing.” He also explains how he enjoys working with the people involved in the collaboration and how the people have made the collaboration a joyful and successful endeavor. “That building of community is why it has been so much fun around here. We have attracted these characters…It is just a delightful group of people to be with. And all of this other stuff we get done is just an outflowing of the fact that we all basically like each other.”

**Education Researcher**

While researching and participating in the collaboration, I too benefited in many ways. Besides the valuable information I gathered from the research, I gained personally as well. For instance, as with the other participants, I also learned a great amount of science content from others during the field trips and from helping to prepare the curriculum. After the field trip about birds I reflected in my journal about how I was astonished at how a whole new area of interest was opened up to me.

All of this work towards the field trip has made me very interested in birds. I am actually surprised because I have never been that interested in birds. I bought a bird field guide and I am starting my life list. You really do learn a lot from having to teach something.

In addition, I learned more about formal education, the students, and the teachers. I became keenly aware that the students were often at various levels academically even though they were in the same class. After one field trip I wrote,

> From the fourth grade, the two groups I had differed greatly in cognitive ability. I even had one kid that did not know his letters, while the other group was taking great data. This was an astonishing and sort of sad revelation to me. I never realized just how cognitively different two students could be and still be at the same grade level. This made me realize what a tough job the teachers must have teaching at such vastly different levels. Moreover, through getting to know the teachers at the school on a personal level, I became more aware of the pressures that bombarded them. Because of my greater awareness and appreciation of the challenges in formal education, I feel that my ability to teach elementary students in both formal and informal settings has improved. I suppose I
had already known that students have different preferred ways of learning, and that it is necessary to adapt instruction accordingly. However, I had never really experienced it in such a real manner. From my experiences on the field trips, I feel like my teaching improved over the year. I reflected upon this development in my journal,

At first I felt like more of a tour guide than a teacher on the trips, just pointing out interesting things. Now I feel like I am letting the kids be more in control of their learning and what interests them. I ask better questions of the students and I know more ways to engage the different kids, whether it is writing, or drawing, or collecting, or discussing.

I gained much knowledge and insight into both teaching and learning through this experience. My experience in the collaboration has made me realize the importance of observation and apprenticeship in both pre-service and in-service professional development. Getting to know the practitioners and spending time in both the formal and informal educational settings has provided me a deeper understanding of the different practices, perspectives, and politics in each of these fields.

Another fortunate outcome of the collaboration was that I really enjoyed myself. First and foremost, I took pleasure in getting to know all of the people involved. I was able to get to know many different people from various walks of life with diverse interests. Many of the collaborators are sure to always be my life-long friends. I also thoroughly enjoyed working with all of the students over the course of the year. Furthermore, I enjoyed the field trips and experiencing nature. After one of the field trips I commented in my journal, “I never knew how beautiful those birds were up close. I was loving it as much as the kids were.” A sense of ownership and passion grew each time I visited the site.

In summation, we all benefited from the collaborative experience in our own distinct, yet similar ways. Every person in the collaboration learned something, whether it was science content, or about different practices in education, or about collaboration in general. In addition, each of us improved our own teaching abilities in some way. Furthermore, this was
an enjoyable experience for all the collaborators and created a sense of enthusiasm in all of us for this type of educational practice.

**Significance/Implications**

**Conclusions**

The main goal of the collaboration was to create beneficial learning opportunities for the students by integrating field trip experiences into the elementary school curriculum. This is exactly what happened. However, not only was the curriculum improved, but also many of the educators’ perspectives on teaching and learning were transformed in a positive way as well. These dramatic changes within the elementary school did not occur because of money or power. These changes are attributed to interactions of individuals within a collaborative environment.

As found in other collaborative research (e.g., Barufaldi, 2000; Mattessich, et al., 2001; Spector, et al., 1995), the critical component to the success of this collaboration was the participants’ shared vision. Although this vision was broad in scope and somewhat vague at the start of the collaboration, it developed into a much more defined and truly shared vision through communication, negotiation, and experience. Communication, and the time to communicate were major factors in achieving a more shared vision. Effective communication allowed us to gain a better understanding of each other’s viewpoints. Although trying to gain a better understanding of each other’s perspectives was time consuming, it was worth the effort because this is where the real learning of other teaching practices occurred. In addition, communication helped motivate the other teachers by providing them with more information about the program and our intentions. A combination of communication, openness to understanding others’ viewpoints, as well as a heightened sense of ownership and dedication to make the field trips educational contributed to a more shared vision, better educational
experiences for the students, and a more valuable professional development experience for the collaborators.

This study provides additional support for the idea that collaborations within the science education community can produce effective professional development opportunities for each of the collaborating science education stakeholders. It is an example of how views of teaching and learning as well as education in general can be transformed through collaboration. The specific types of professional development opportunities that this collaboration produced included:

1. Learning—This included learning science content, learning about different cultures in education, learning about better teaching practices, and learning about collaboration.
2. Improved teaching practices—This included teaching at a more appropriate level for the students, adapting to different learning styles, and integrating field trips into the curriculum.
3. Enjoyment and enthusiasm—This included improved attitudes toward both science and education in general, an increased faith in collaboration, and enjoyment from working with the others in the collaboration.

This case is a good illustration of how an entire science education community can learn and evolve together as a shared vision is created through collaboration and thereby demonstrates how collaboration can be an effective tool for science education reform.

Promoting the Development of Similar Collaborations
It is important to keep in mind that every collaboration will be different because of different participants, different places, and different situations. Each collaboration will have to figure out the best way of working together and will have to do the collaborative work of communicating and striving to understand the perspectives of the other collaborators in order to form a shared vision.
However, in light of the components deemed essential in this collaboration and their concurrence with important factors in other collaborations as illustrated in the education literature, I have a few recommendations for encouraging the development of other similar collaborations. First and foremost, you need people that are motivated and committed to collaborating. One way to increase the number of collaborators is to teach education students (preservice, and inservice) how to collaborate. Although a course on collaboration would be appropriate in any department, and certainly other potential collaborative participants such as scientists, informal educators, and researchers could benefit significantly from a greater knowledge of collaborative skills, it is the teachers that need to understand the benefits of collaborating during curriculum development because they will determine whether or not it gets presented to their students. Educators should be given insight into developing shared vision using skills such as effective communication and understanding others’ perspectives and cultures. They need to learn about their collaborative resources, including community members in informal education and at local colleges and universities. Moreover, teachers need to learn about the potential benefits of collaboration, both for themselves and their students.

Furthermore, there needs to be a system-wide effort to help prime institutions for collaboration. Key personnel at education institutions need to be educated on the virtues of collaboration in education. Home institutions need to provide educators with time specifically dedicated to collaboration and more rewards for their collaborative endeavors. This will help encourage collaboration among science education practitioners by creating a more collaborative environment.

**Future Research**

The process of studying this collaboration raised many additional questions including some pertaining to this particular case, as well as those pertaining to the larger discipline of collaboration within education. For example, each of the collaborators mentioned that one of
the benefits that they received from participating in the collaboration was that they learned much about teaching and learning. However, will the participants’ improved teaching and learning skills and knowledge carry over into contexts other than the domain of the field trip curriculum? For instance, will the scientists continually carry over some of their newly acquired teaching skills to their university classes? Will the elementary teachers start to teach more in-depth and at a higher level in other areas of their curriculum?

Furthermore, it would be interesting to synthesize information about different collaborations, in different contexts, and from different perspectives. Because the situation changes with different collaborators, in different environments, and under different circumstances, it is difficult to generalize the professional development benefits of this case to other collaborations. What might emerge from a meta-analysis may have greater impact on education reform efforts, because more generalizations could then be made.

Even though the study cannot be directly generalized to other collaborations, the issues that arose in this case can be used as springboards for further investigations. For instance, this is an example of a rather small-scale collaboration. In this case, the smallness of the collaboration may have made it possible to succeed. It allowed us to get to know each other, understand each other’s perspectives, and communicate more effectively. The secondary participants in the collaboration, (i.e., the other teachers not directly involved in the collaboration) were much harder to reach due to less direct communication. It took much longer to understand their needs and for them to gain ownership and dedication towards the program. What does this mean in terms of having larger-scaled collaborations which affect entire school districts? How can more far-reaching collaborations be created while still keeping the trust, ownership, and communication that was so important for this smaller collaboration? Is this possible, or is it necessary to have several smaller, local collaborations in order to produce the same types of professional development benefits?
After having participated in this collaboration I am optimistic about the prospects for systemic reform in science education, and I am convinced that collaboration is the key. I am confident that this case can function as an example of how collaboration can be an effective tool for science education reform. Furthermore, I am hopeful that this case can provide insights to practitioners in science education and in other fields wishing to bring about change through collaboration.

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Campus Performance. [online].

“I WON’T LAST THREE WEEKS”: PRESERVICE SCIENCE TEACHERS REFLECT ON THEIR STUDENT TEACHING EXPERIENCES

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Abstract

In many teacher preparation programs, student teaching serves as a culminating event which attempts to bridge academic coursework and the realities of classroom teaching. Therefore, it represents a significant aspect of preservice teacher education. This study explores student teaching as it is experienced by thirteen middle and secondary science preservice teachers. Qualitative techniques are used to analyze individual interviews, group seminar sessions, and written reflections in order to construct a phenomenological account of student teaching as experienced by the preservice teachers. The aim is to construct a picture of the shared experiences of these student teachers to help understand how they struggled, succeeded, and learned as a part of their classroom practica. These findings are then used to draw implications for science teacher education. This paper represents the first report of a longitudinal study of the experiences of individuals as they transition from students to beginning teachers to experienced educators.

Introduction

Toward the end of the year, he [my cooperating teacher] confessed to telling his colleagues I wouldn’t last three weeks, which is funny because I conveyed the same sentiment to my friends at home after my first week. (Oscar)

Oscar’s comment above provides a vivid depiction of the stress, anxiety, and uncertainty felt by preservice teachers (PST) as they begin their student teaching experiences. In many teacher preparation programs, student teaching serves as a culminating event which attempts to bridge academic coursework and the realities of classroom teaching (Kagan, 1992). For some PST, student teaching offers their first opportunity to actually work with K-12 students; and for many, it serves as the final preparatory activity before they assume the full responsibilities of a practicing teacher. Like PST in all disciplines, science PST must negotiate classroom management, school policies, relationship building with students, organization, lesson planning, and their own positions within the social structure of the schools (Kuzmic, 1994). Science PST also face challenges unique to the subjects they teach such as incorporating scientific inquiry, planning and securing resources for laboratories, and
safety concerns just to name a few. While there have been several studies of student teaching (e.g., Borko & Mayfield, 1995; Chandler, Robinson & Noyes, 1994; Yerian & Grossman, 1997), most have not focused on student teaching in a science context; although, some notable exceptions do exist (Crawford, 1999; Lederman & Gess Newsome, 1991). Many of the studies specific to science teacher development and concerns have concentrated on the induction phase which is usually defined as the first few years of full time teaching (Adams & Krockover, 1997; Luft & Cox, 2001; Luft & Patterson, 2002; Simmons et al., 1999). This study contributes to the area of science teacher development by providing a phenomenological account of the student teaching experience as interpreted by thirteen science PST. More specifically, the study seeks to understand how science PST conceptualized, valued, and struggled with their student teaching experiences.

Theoretical Framework

In their review of research on teacher development, Wideen, Mayer-Smith, and Moon (1998) question traditional notions of the role of student teaching in teacher education programs. Traditionally, student teaching has been thought of as an opportunity for PST to apply knowledge and skills, gained at the university, in actual classroom settings. PST are challenged to use theory provided in their university programs in the authentic settings provided by their student teaching placements (Britzman, 1986). Wideen et al. (1998) conclude that the distinct goals and tension among teacher educators, PST, and cooperating teachers as well as the divergent cultures of universities and K-12 schools invalidate this traditional view of student teaching. As an example, one of the patterns that emerged from the reviewed studies was the tendency for teacher educators to conceptualize the student teaching experience as a time for PST to experiment with and reflect on innovative teaching approaches; whereas, the PST more often saw student teaching as a challenge they must attempt to survive. These varying perspectives left teacher educators disappointed by a
perceived lack of progress among their student teachers and PST frustrated with perceived inadequate preparation for the challenges presented by real classrooms.

Wideen et al. (1998) propose a re-conceptualization of teacher education including the student teaching experience. In the following quote, they contend that a complete reorganization of teacher development programs is necessary in order to affect meaningful change. “We would argue that applying alternative approaches within existing programs of teacher education which are based upon a ‘training model of learning to teach’ is rather like rearranging the deck chairs on the Titanic” (p. 167). They point to the success of professional development schools (PDS) as vehicles for fostering prolonged collaboration among university educators, classroom teachers, and PST (Levine, 1992). Crawford & Kreamer (2004) have recently reported on the benefits to both PST and their cooperating teachers as they worked in a PDS-university collaboration specifically focused on enhancing science teaching and learning. As a researcher and teacher educator, I have no doubt that restructuring PST education in ways that situate PDS collaborations as a central theme would be constructive. However, I question the conclusion that teacher development within more traditional programs is tantamount to moving furniture on a sinking ship.

It might be the case that PST education is best served in situations where there are extended interactions and collaborations among PST, university educators, and cooperating teachers particularly in the context of PDS. Unfortunately, serious constraints may make this arrangement unlikely or even impossible in many settings. The responsibilities and expectations of university faculty members and K-12 teachers do not always facilitate the kinds of interactions envisioned. Furthermore, structural elements may present additional obstacles. For instance, consider the case of a large university with a substantial PST population situated in a small town or rural area. In this situation, the goals of a progressive teacher education program can overburden the local school district creating the potential to
foster resentment rather than collaboration. While teacher education in PDS may serve as a useful model, scaling such programs up for large teacher preparation programs, especially in non-urban/suburban settings, would be difficult if not impossible.

In a discussion of moral education, Green (1988) draws distinctions between ideal, educationally superior worlds and the real world in which teachers and teacher educators work. He suggests that educational settings are often not representative of the best possible situation; education is constrained by actuality and that frequently means teaching and learning in a less-than-ideal world. I believe Green’s perspective can be useful in thinking about student teaching. Many teacher education programs do not and cannot adopt approaches as progressive as those advocated by Wideen et al. (1998). The student teaching experience cannot always be as intimately coordinated with other aspects of the teacher preparation program as desired; and yet, the experiences may still be instrumental for the PST. Teacher educators do have some leeway in traditional programs to structure and facilitate student teaching experiences so as to meaningfully affect PST learning. To extend Wideen et al.’s (1998) metaphor, innovative approaches embedded within existing teacher education programs may not be analogous to the ideal of equipping the Titanic with advanced navigational equipment which would eliminate any possibility of a collision, but they are probably not as perfunctory as rearranging the deck chairs. Perhaps teacher educators in traditional programs seek to accomplish some middle ground rather like readying the life boats or helping passengers understand what they might do if the ship starts sinking. This perspective framed the current investigation of student teaching in the context of science. The experiences of PST during their student teaching are important for teacher educators to understand, even in traditional contexts, in order to enhance teacher preparation programs.

Overview of Related Literature
Even experienced practitioners often struggle with the challenges presented by teaching, so it is not at all surprising that novice teachers present a number of concerns. Adams and Krockover (1997) reported a series of beginning science teacher concerns including difficulties with time management, classroom management, the presentation of content, and curriculum development. Lederman and Gess-Newsome (1991) identified similar concerns among science PST and organized them in two general categories in terms of their focus: either focused on self or their students. Concerns related to self included worries about classroom presence and content mastery; whereas, student-related concerns included classroom management and rapport. These patterns are also reflected in reviews of the literature which focus on teacher preparation in contexts broader than just science programs (Kagan, 1992; Veenman, 1984; Wideen et al., 1998).

Another common finding presented in literature related to teacher induction and to a lesser extent student teaching has been termed “praxis shock” (Kelchtermans & Ballet, 2002). Beginning teachers are often overwhelmed by the demands of the profession and shift from idealistic notions of teaching to pragmatic approaches, which are often very traditional and contradictory to the aims of many teacher preparation programs (Kagan, 1992; Wideen et al., 1998). Drawing from an in-depth case study, Kuzmic (1994) documents how a beginning teacher’s idealism and enthusiasm for innovation are suppressed by the unexpected realities of her school. The beginning teacher’s greatest struggles involved school bureaucracy and aspects of the job seemingly unrelated to teaching and learning.

Empirical results also reveal a number of student and beginning teachers’ reflections on how their preparatory programs contributed to or inhibited their success. A great deal of evidence suggests that beginning teachers do not feel as though their teacher education programs prepared them well for the challenges of real classrooms and schools (Adams & Krockover, 1997; Kagan, 1992; Wideen et al., 1998) citing instruction regarding classroom
management (Rust, 1994) and the politics of education (Kuzmic, 1994) as specific examples of how their training fell short. The subjects in Adams and Krockover’s (1997) study suggested that science content courses were too specific and not applicable to K-12 teaching contexts, but that opportunities to practice teaching as undergraduate teaching assistants was very helpful. This group also cited the need for more field experiences to help orient PST to K-12 classrooms. In contrast to these generally negative findings regarding the perceived usefulness of teacher training programs, Loughran’s (1994) sample of 2nd year science teachers offered favorable reflections on their preparatory programs.

Research Focus

The purpose of this study was to explore PST reflections on their own student teaching experiences. Through individual interviews, group seminar sessions, and written reflections, I sought to build a phenomenological account of student teaching as experienced by thirteen secondary science PST. The aim was to construct a picture of the shared experiences of these student teachers to help understand how they struggled, succeeded, and learned as a part of their classroom practica.

Program Description

The participants in this study were involved in a middle and secondary science teacher preparation program at a large Midwestern public university. These thirteen individuals comprised about two thirds of a cohort which completed student teaching and became eligible for licensure in fall of 2003. Although these PST shared a common science methods course, which was associated with student teaching, and participated in a seminar designed to support the student teaching experience, they came to the program from a variety of backgrounds. Seven participants were undergraduate students seeking Bachelors degrees in science education. These students completed extensive coursework in at least two of the traditional science disciplines. The remaining six individuals were Masters students who had already
earned undergraduate degrees in a science content area; some were completing an M.A.T. (Master of Arts in Teaching) awarded by science content departments, and others were working towards an M.Ed. (Master of Education) with an emphasis in science education awarded by the School of Education. Regardless of the track, all participants had completed coursework in educational foundations, technology, psychology, multiculturalism, and content-area literacy. In addition, they had completed an introductory methods course specific to middle and high school science instruction. This course was accompanied by a field experience during which students spent a minimum of 30 hours in a local middle or high school. During the student teaching semester, which was the final semester preceding graduation for all of the study’s participants, students participated in a six week intensive advanced methods course, completed a 40 hour field placement in the classroom in which they would ultimately student teach, and participated in a professional development seminar designed to support the student teaching experience. During the first six weeks of the semester, participants attended daily classes at the university and spent several hours per week in the classrooms in which they would work during student teaching. The nature of their involvement in their classroom placements varied substantially based on their own comfort level and the plans of their cooperating teachers. Whereas some assumed major teaching responsibilities, others did little more than observe during the first six weeks. Student teaching officially commenced at the beginning of the semester’s seventh week. Ideally, participants should have taken over classes immediately and taught a full load by the end of the seventh week; however, this too varied among PST and cooperating teachers. Full-time student teaching lasted ten weeks making the entire practicum experience sixteen weeks in length. The entire cohort met for bi-weekly seminars at which time students shared experiences, offered support to one another, commiserated, and reflected on their teaching. As one participant remarked, the seminars were “group therapy for student teachers.”
Researcher Biases

I served as the instructor for the second methods course which was taught during the student teaching semester as well as the seminar facilitator. Prior to the student teaching semester, I had no personal interactions with any of the students involved, but having worked together everyday for six weeks, we quickly developed relationships. By the time data were being collected for this study, I knew all the participants very well. Given the qualitative nature of the study, these close relationships can be viewed as both strengths and weaknesses. I was never positioned as an unbiased observer; rather, I was personally engaged with all of the participants. These personal relationships certainly influenced the manner in which I interacted with the participants, and although I remained conscious of potential problems and worked to avoid them, the relationships could have also affected my analyses. Our previous interactions could have also influenced the responses participants offered during the interviews. On the other hand, these relationships afforded me opportunities to which a less involved researcher might not have had access. The participants and I were on first name bases and were comfortable talking to one another. Although I generally followed a semi-structured interview format, the interviews were conversational in nature and flowed freely allowing participants to explore their own ideas with ease. Less familiar interview contexts can be adversely affected by anxiety and tension (Eisner, 1991). My role as a member of the cohort’s community also allowed me to contribute to the seminars during which the participants confided in one another and shared personal stories of success and adversity. The emic perspective I achieved certainly has the potential to affect the kinds of conclusions drawn as a part of this study, but it is this emic perspective which enabled me to collect the kind of in-depth data necessary for gaining perspective on PST experiences.

Methods

Sample
The thirteen PST who participated in the study were recruited at the conclusion of their student teaching experiences through the seminar which was required of all cohort members (i.e., middle and secondary science student teachers). The six cohort members who did not participate chose not to complete an informed consent form, became too busy to complete the interview, or were not present during the seminar session at which individuals were recruited. Four of the participants reported teaching 7th and/or 8th grade science classes, and the other nine taught high school science courses including biology, chemistry, and physics. The student teachers worked in classes of varying levels from below average to Advanced Placement. Six participants taught one subject preparation (prep); five PST managed 2 preps; and the other two individuals worked with three preps. This variation was due entirely to the teaching responsibilities of the cooperating teachers who mentored the participants. Gender distribution was fairly equal with six female participants.

Data Collection

Data were supplied from three different sources: interviews, written reflections, and seminar field notes. I conducted individual interviews with each of the participants in a private office at the conclusion of the student teaching experience. All of the interviews took place 1 to 3 months following the completion of student teaching. Each was audio-taped and transcribed for analysis. The interviews followed a semi-structured format: they proceeded in a conversational fashion but were guided by a set of questions. The interview protocol (see Appendix A), which was informed by the literature reviewed earlier, was designed to encourage participants to explain student teaching as they experienced it.

As a part of their university coursework, all participants wrote a series of reflections throughout the field experiences (prior to student teaching) and student teaching. At the conclusion of student teaching, participants completed a comprehensive “final reflection” designed to encourage students to reflect on and discuss the successes and problems they
experienced throughout student teaching. The participants were asked to think about what they learned and how the experience affected their teaching. The excerpt below was taken from a course syllabus and describes the assignment.

You will prepare a final reflection focusing on your entire student teaching experience…Think about what you’ve learned (and still need to learn) in terms of planning, delivery, assessment, classroom management, inquiry, conducting laboratories, managing resources, the thrill of molding young minds, etc.

The written, final reflections were an additional source of data.

The third data source was field notes taken during the student teaching seminars. During the ten weeks of student teaching, the entire cohort met one evening every other week to share experiences and insights. I facilitated these meetings which typically lasted for about two hours and were informal in nature. A typical seminar began with a few announcements and a focus question or two, which I provided, such as “how have you handled discipline issues?” or “what kinds of activities have you tried?” In every seminar, student discussion filled the rest of the meeting. I offered comments and suggestions when appropriate and took extensive notes on the student-generated concerns and ideas. These notes served as a final data source.

Data Analysis

The qualitative analysis proceeded in four stages. Member checking was the focus of the first stage. I reviewed interview transcripts and the final reflection for each participant and prepared a summary of my interpretations. These summaries were mailed electronically to each participant for their comments. Eleven of the thirteen participants responded, and all suggested that my interpretation was substantively appropriate. Two individuals made very minor corrections.
The second stage was an inductive analysis of the data (Lincoln & Guba, 1985) consistent with the constant comparative method (Glaser & Strauss, 1967). The interview transcripts and reflections served as primary data sources for these analyses. I identified several recurrent ideas within and among participant data sets. These categories were then compared and contrasted in order to form more general themes which captured larger aspects of the data. Having identified emergent categories and themes, I went back through the data sets in order to identify specific excerpts which signaled these groupings so as to ground the analysis in the data.

Peer debriefing was the focus of stage three. Another reviewer examined five data sets in order to independently establish the emergent categories. The reviewer identified a majority of the same categories and themes that I originally documented. In most cases, we had named categories differently, but the underlying themes were consistent. She also examined evidence of themes not present in the limited data sub-set to establish coherence and plausibility of the complete taxonomy. After discussions of the data and interpretations, we established consensus on the final taxonomy.

In the final stage, I used the seminar field notes as a secondary data source to corroborate the emergent categories and themes. Given the qualitative nature of the study, the findings are necessarily tied to the context of this particular study and applicability is shifted to the reader as s/he can most appropriately determine the extent to which the PST involved in this study are reflective of other beginning teachers (Lincoln & Guba, 1985). The actual frequency of any particular category is far less significant than its occurrence, but in establishing what constitutes a category versus an isolated experience, I have rather arbitrarily set the occurrence level at three. The patterns discussed in this report were expressed by a minimum of three individuals in any of the data sources. The quotes provided throughout the
Results section were excerpted from interview transcripts or written reflections. All of the names provided are pseudonyms.

Results & Discussion

Given the qualitative nature of the analyses, discussion is embedded in the presentation of results. Participant reflections on their student teaching experiences were grouped into five overarching themes: challenges, successes, supports, knowledge gains, and ideal teaching. It should be noted that some of these themes parallel interview questions that were posed. However, the themes were also prevalent in the written reflections and field notes. While it can be reasonably argued that the structure of the interviews affected the kinds of topics discussed, the more specific patterns or categories subsumed by these themes were far less influenced by the process of data collection. The fact that these ideas surfaced in multiple data sources, including the PST written reflections and seminar field notes both of which occurred prior to the interviews, supports the notion that these categories are truly reflective of the participants’ ideas. In the text that follows, emergent patterns subsumed by the five overarching themes are discussed. To support the legitimacy of the patterns discussed, tables are used to present representative comments offered by the participants. As mentioned in the Methods section, all of the patterns identified and discussed emerged from the comments of at least three participants.

Challenges

Participants discussed a number of factors which created challenges for their student teaching. These difficulties included classroom management, time management, institutional and job complexity, unengaged cooperating teachers, university requirements, and special needs students. Classroom management was further subdivided to reflect more specific concerns. Several participants originally adopted relaxed approaches to classroom management and found that this created immediate problems. Others struggled with when and
how to impose discipline or enforce rules. They had difficulty establishing their own
tolerances and found themselves trying to decide when it was necessary for them to step in
and encourage students to change their behaviors. For instance, Tara clearly knew that she
needed to address a student as he began shooting staples into his own arm, but she found it far
more difficult determining at what point she should make the class quiet down as the noise
level grew in the midst of an activity. Others found their unique status as student teachers as
an impediment to establishing discipline within the classroom. These participants discussed
the fact that their students saw them as different from the “real” teacher, a situation which was
exacerbated by the fact that many were not that much older than the high school students and
had very youthful appearances. Another group of participants felt that their classroom
management problems stemmed from a lack of discipline prior to their assumption of
classroom control. These individuals felt that they were set up for failure because the classes
they began teaching had not been properly managed in the first place. Participant comments
are presented in Table 1 to support the legitimacy of these interpretations.

Time management was another problematic issue for the student teachers. Time
management challenges included dealing with demands on the participants’ own time as well
as negotiating classroom time. In terms of their own time, many participants felt
overwhelmed by the amount of time required to develop lesson plans and classroom activities.
They generally felt confident in their own abilities to come up with good curricular plans, but
they never had enough time to complete the planning required. Contributing to this perceived
problem was the burden of grading. In particular, the individuals who really worked to infuse
inquiry in their instruction expressed frustration with the time and effort required for adequate
assessment. Some of the participants also discussed how parental communications,
particularly via email, consumed a great deal of their time. In principle, email sounded like an
ideal means of sharing information with parents, but several of the participants felt inundated
with email messages from parents requiring them to devote considerable time to constructing responses. In terms of class time, participants noted difficulty in estimating instructional time required for certain topics. Some individuals reported that they consistently under-planned while others never allotted enough time for group work and labs. Finally, several participants struggled with covering the amount of material expected by their cooperating teachers. Given the current climate of standards and accountability this pattern is not unexpected nor is it unique to student teachers (Abrams, Pedulla, & Madaus, 2003).

Many participants were challenged by the complexity of their responsibilities and of schools as institutions. They found it difficult to complete all that was asked of them such as maintaining accurate records, organizing student assignments, recording absences, and administrative responsibilities. The issue of institutional and job complexity surfaced often during the seminar meetings; the student teachers shared their struggles and offered a variety of strategies for dealing with these issues. Another prominent challenge was unresponsive and unengaged cooperating teachers. While many participants discussed very positive experiences with their cooperating teachers, several cited their cooperating teacher as a fundamental problem with their student teaching placement. These participants cited an unmet desire to receive critical feedback on their planning, instruction, and management strategies. Others were concerned more with supervision and requirements from the university. A university supervisor, who was a retired teacher or school administrator, worked with each student teacher. The university supervisor’s expectations varied greatly, and some of the participants felt that the work required of them was onerous, unnecessary, and unrelated to their teaching responsibilities. While it is possible that some of the participants’ complaints were unwarranted, it appeared that at least some of the supervisors’ expectations were unrealistic and burdensome. For instance, in addition to full-time teaching and seminar participation, Ted was expected to read and discuss a few books, respond to late-night phone calls, and prepare
daily lesson plans using an unfamiliar and very detailed format (far beyond what was deemed acceptable by his cooperating teacher and the methods course requirements).

The final challenge which was expressed by a significant number of participants was dealing with special needs students. I use the phrase “special needs students” because this is the phrase that many of the participants used, but it should be noted that this title includes a wide variety of students. For some participants, it included all of the students who were dissimilar to themselves in terms of academic motivation, aptitude, and success. They talked about the challenges of working with English-as-a-second-language students, learning disabled students, and “lower level” students. For some of the participants, any students who were not on the fast track to college were lower level. Many of the student teachers struggled with effective ways of reaching these students and felt ill-prepared by the university to do so.
### Table 1
**Taxonomy of Challenges Experienced during Student Teaching**

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Specific Concern</th>
<th>Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Classroom Management</strong></td>
<td>Students took advantage of relaxed approaches</td>
<td>“Going into the whole experience, I was told don’t go in there and smile for however long, but that is just not me. That is not my personality to just go in there and be extremely strict right off the bat. I kind of went in—not that I wanted to be friends but just be myself and at times that came back to haunt me. I definitely need to work on that [management].” (Ted)</td>
</tr>
<tr>
<td></td>
<td>Establishing tolerances</td>
<td>“Knowing when to say when as far as classroom management [was challenging]. Like students got chatty or above the level of noise I like in a classroom. I felt uneasy telling them to be quiet or something like that…I had to feel them out as far as when to tell them to quiet down and when not to. I had to figure out what was actually horseplay.” (Steven)</td>
</tr>
<tr>
<td></td>
<td>Unique status as student teacher</td>
<td>“At first, I did not feel comfortable doing any kind of discipline or management because I felt like it was not my place, but then as I took over more classes, I kind of had to. They [the students] were a little bit resistant because I was younger and I was a student teacher or whatever…They did not see me as an older more experienced teacher and so it took a lot to get their respect.” (Ella)</td>
</tr>
<tr>
<td></td>
<td>Taking over a bad situation</td>
<td>“As far as management goes, before I got there, he [the cooperating teacher] did not seem to care if the students were throwing things or talking back or not paying attention. It was hard to keep control…I never felt that I was actually teaching; I just felt like I was babysitting.” (Thelma)</td>
</tr>
<tr>
<td><strong>Time Management</strong></td>
<td>Planning</td>
<td>“My biggest fear is to be under-prepared walking in and not being 100% sure of what I was doing, so I spent a lot of time preparing. I went in on Saturdays and worked just because for me it was worth it for me to be more confident and comfortable with what I was doing. That was the biggest challenge just time management. It just seemed like if I was awake I would be doing something for the class.” (Neil)</td>
</tr>
</tbody>
</table>
Grading

“Like inquiry is emphasized a whole lot and what ended up happening is I would get massive amounts of grading all at once and I think that was a big challenge. How the heck am I going to deal with this?” (Tara)

Parental Communications

“Keeping up with all the parent’s emails [was challenging]. There are a lot of parents constantly checking up on their kids. My whole prep period was spent responding to emails… Everyday I would get 4 to 5 emails from parents asking how their kids were doing and what was coming up and why their kid had this grade. My whole planning period was gone.” (Wendell)

Class time

“I had some problems trying to get enough to do in the class time because it was block scheduling. If we went too short, I’d have to come up with something so that they [the students] were doing something.” (Sal)

Covering material in the time allotted

“I usually felt really rushed [to cover more material]. In finishing the first trimester we had two sections to cover in about eight days total…It was like impossible trying to get the students through it and hoping they got something out of it. I remember looking at it and thinking I do not even know how I will tackle this let alone getting the students to understand or remember anything.” (Feran)

Institutional & Job Complexity

“Just learning the ropes was hard. You have to have content knowledge and a general understanding of how education works but finally putting it all together and seeing this is what I have to do for the kids and this is what I have to do for the administration and make sure that I do this—throwing everything together and making sure that it all works is the biggest challenge.” (Tara)

Unengaged Cooperating Teachers

“Some of the hardest things was just trying to get feedback. I felt like there were times when I was not really sure how things were going and I did not get a lot of constructive feedback. I was just like, ‘oh well, that will get better with time,’ but that did not do much good for me in terms of what about the lesson-what specifics about this lesson should be changed.” (Feran)

University

“My university supervisor would not let me get
away with writing simple lesson plans. So, I had to have a whole lesson for every single day that I was teaching. That was the most difficult thing because it took time to put it into this specific format and write out exactly what was going to happen. Sometimes, I just felt like I was copying definitions from the book.” (Eileen)

“The most challenging part was learning how to teach to the lower students. That was very hard. I taught here [at the university] for three years and I thought I’d be ready for a chemistry and an AP biology course, but even in these classes there was still that bottom 30-40%. Initially, I just sailed right over their heads. I did not know what to do about it, and the test scores reflected that.” (Irvine)

### Successes

Despite the difficulties they experienced, the participants also noted several successes. They reported achieving success at relating well to students, delivering individualized instruction, making content personally relevant to their students, reflecting on their own teaching and making appropriate modifications, and structuring inquiry experiences.

Participants noted several ways in which they successfully related to their students including developing good rapport, knowing when their students were confused, and reaching students who had previously been unengaged. Several participants discussed how they developed good rapport with their students which had the effect of creating positive learning environments. Others reported that they were particularly adept at determining when students had trouble understanding content material that was being covered. Several were also successful in encouraging students, who had not been participating in class or just not doing well before the student teacher arrived. Table 2 presents interview and written reflection excerpts which support these categories.

Several participants reported achieving success when using individualized instruction. They seemed to excel when given an opportunity to connect individually with students. Some
also reported on the productive use of reflection. These student teachers took time to carefully reflect on what was and was not working in their classrooms and made appropriate modifications. Finally, several suggested that they had successfully incorporated inquiry-based instruction. Although this encouraging result is supported by other studies (Crawford, 1999), it must be tempered by findings (Lotter, 2004) which suggest that PST interpretations of inquiry often differ substantially from those offered in the *National Science Education Standards* (National Research Council, 1996). An admitted limitation of the current study is that it did not involve classroom observations which could have confirmed the extent to which participant instruction reflected inquiry; however, some participants (albeit a minority) offered descriptions of their teaching practices that were reflective of inquiry as defined by the *National Science Education Standards*. 
<table>
<thead>
<tr>
<th>Success</th>
<th>Specific Accomplishment</th>
<th>Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relating Well to Students</td>
<td>Good rapport</td>
<td>“I am good at setting up a positive atmosphere. I think I do my best to set up an atmosphere where students know that they’re going to work but they’re also going to have fun.” (Neil)</td>
</tr>
<tr>
<td></td>
<td>Knowing when students were confused</td>
<td>“I think I’m pretty good at relating to the students…I am pretty aware of what is going on. If they are understanding or not understanding—if they are listening or if they’re talking about the subjects or just something going on during the weekend.” (Ella)</td>
</tr>
<tr>
<td></td>
<td>Reaching previously unengaged students</td>
<td>“I was able to get to those hard to reach kids. There were students who would not even look at me during lectures and stuff. They didn’t turn in any homework and failed the tests…So, I pretty much sat down with them and asked them what they were looking for in the class. They said, ‘I do not want to be in here. I do not need chemistry; I’m just stuck in it.’ I just leveled with them and told them what I expected of them after I heard what they expected of me and worked out arrangements. Through their grades, I realized that I was getting through to them more.” (Oscar)</td>
</tr>
<tr>
<td>Individualized Instruction</td>
<td></td>
<td>“I am definitely good at one-on-one interactions with students. I like sitting down after school and before school and really taking students who are having trouble and wanting to get better and working with them and having good result with them. That is probably my strongest point as a teacher.” (Irvine)</td>
</tr>
<tr>
<td>Making Content Personally Relevant</td>
<td></td>
<td>“I try to bring my own experiences into things. If I have a story that helps explain a certain point or if I can somehow find something that is current in science to talk about as I’m talking about something that is kind of dry might make it more interesting. I try to address the question, ‘why in the world would we ever need to know this?’ and make things more relevant.” (Steven)</td>
</tr>
<tr>
<td>Reflecting</td>
<td></td>
<td>“I think I am really good at adapting—at reflecting</td>
</tr>
</tbody>
</table>
on what went well and what did not go well. In a particular lesson or a particular situation with a student and then making changes. I called it ‘working out the kinks.’ I think that is my biggest asset, because I might not do something right the first time, but the second time I will know more about how to make it better.” (Oscar)

**Structuring Inquiry**

“I wrote some good labs and adjusted some [more traditional] activities to make them more inquiry-based. They [students] had opportunities to work together and really answer some questions.” (Thelma)

**Supports**

Participants also discussed some factors which they felt were helpful to them or beneficial to their student teaching experience. Some of these factors were external in that they were supports provided to the students. Several participants discussed characteristics or behaviors of their cooperating teachers that were very helpful. These included providing specific feedback and advice, outward expressions of encouragement and specific praise, and granting full control of the classroom. With respect to this last characteristic, the participants appreciated ideas and suggestions provided by their cooperating teachers, but this was most helpful when the participants ultimately possessed the freedom to choose how suggestions would be implemented. Science methods courses were also perceived as external supports. Many participants cited specific ways in which these courses were helpful such as lesson planning in a science context, formulating objectives, asking questions, and lesson ideas. It should also be noted that positive comments regarding the methods courses were usually paired with negative comments regarding more general education coursework. Several participants reported that the general education coursework failed to provide practical strategies for dealing with real classroom problems.
Internal supports, those factors which were controlled by the participant him/herself, included a willingness to invest oneself in the school community and their knowledge of content. Interactions with the school community were described in terms of seeking out the expertise of teachers, in addition to the cooperating teacher. Participants also went out of their way to assume an active role in the extracurricular activities of the school. For instance, some helped coach sports teams and others contributed to school-wide curriculum reform projects. The other internal support was the content knowledge that many participants possessed. Most of the MAT students, who had completed undergraduate degrees in science content areas, made mention of the usefulness of their content knowledge. In contrast, some of the undergraduate participants cited content knowledge as a cause for concern during their student teaching. Table 3 provides data to substantiate these categories.
<table>
<thead>
<tr>
<th>Support</th>
<th>Specific Characteristic</th>
<th>Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperating Teachers</td>
<td>Feedback &amp; advice</td>
<td>“She [the cooperating teacher] would give me activities and tell me how it worked for her and how I might do it... She would help me a lot with quick little activities or mnemonic devices or things like that.” (Wendell)</td>
</tr>
<tr>
<td></td>
<td>Encouragement &amp; praise</td>
<td>“The biggest thing that he [the cooperating teacher] did for me was offer encouragement which really helped boost my confidence in the classroom.” (Oscar)</td>
</tr>
<tr>
<td></td>
<td>Granting classroom control</td>
<td>“I was let loose [in the classroom] and that was best for me. It really prepared me. I had to figure things out like how the school would be run, like passes and homerooms and announcements. Things like that was a great experience.” (Ted)</td>
</tr>
<tr>
<td>Science Methods</td>
<td></td>
<td>“I thought the preparation [for student teaching] was good. The last class [science methods] was most helpful. I wish there were more classes like that. I used a lot of the demos and stuff that we did.” (Thelma)</td>
</tr>
<tr>
<td>Interactions with School</td>
<td>Other teachers</td>
<td>“All of the science teachers were very open with me. I felt like I could talk with them about anything in the school…I also went around to other classes. I went to history class and an English class and it was interesting.” (Ella)</td>
</tr>
<tr>
<td>Community</td>
<td>Getting involved</td>
<td>“I tried to get involved in the community side of it. I did that by helping out with practices for the 7th grade basketball team…I attended things like band concerts to see the kids outside the classroom and to see faculty outside the classroom. It was a really neat experience and helped me relate to students and other teachers.” (Neil)</td>
</tr>
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</table>
| Content Knowledge               |                                    | “I definitely have to say that a lot of preparation in the content area helps me feel confident to teach the area…They [the students] were able to tell that I knew what was going on [in terms of content]. Maybe they were less likely to see me as just a student teacher because I knew what was going
Knowledge Gains

The participants reported that they had learned new things as a result of their student teaching experiences. In some cases, they were confronted with new and unexpected ideas and knowledge. In other instances, existing ideas seemed to be shaped by the student teaching experience. Consistent with the notion of “Praxis shock” described by other authors (Kelchtermans & Ballet, 2002), several participants described how their once idealistic notions of education had shifted to far more pragmatic perspectives. They came to realizations such as not every student can be reached, some students are not interested in learning, there are many constraints on classroom teachers, etc. In a related theme, participants came to a new appreciation of the difficulty of teaching. Wendell talked about how wrong he was to think that teaching was an “8 to 3 kind of job.” In addition to the work load and time commitments, some participants reported gaining new insights relative to the social and political realities of teaching. For example, participants talked about gaining new perspectives on administrative styles, the political pressures of testing, and the significance of personal interactions among faculty and staff.

As a result of their student teaching, several of the participants gained first hand knowledge that inquiry-based instruction was time consuming and work intensive, but that it actually worked in terms of promoting student learning. Some of the participants reported going into the experience with the idea that disseminating science content was the primary goal of science education but left believing that content was only part of the task. They ultimately placed much greater emphases on helping students develop life skills and problem solving skills. Finally, in what I considered to be a very positive result, many participants
declared that student teaching helped them decide that teaching was the profession they wanted to pursue. Table 4 presents participant quotes which support these categories.

Table 4  
*Taxonomy of Knowledge Gains Resulting from Student Teaching*

<table>
<thead>
<tr>
<th>Knowledge Gains</th>
<th>Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Praxis Shock</strong></td>
<td>“When I went into my student teaching, I was incredibly idealistic. I always said that I was going to be able to reach every student...During that first two weeks, all that went out the window...Having experienced it, I have a much more clear idea of what to expect the next time I go into the classroom.” (Oscar)</td>
</tr>
<tr>
<td><strong>Complexity of Teaching</strong></td>
<td>“I was able to understand a little better how things work in a school and a classroom. I was used to thinking primarily about how lessons should go in terms of pedagogy and the content...Going into a classroom and experiencing how a school day goes and how you might have one plan and you do it five different times and it will not come out the same any time...I had to come to terms with the fact that things would change all the time.” (Steven)</td>
</tr>
<tr>
<td><strong>Effectiveness of Inquiry</strong></td>
<td>“I think at first I did not know how I could get kids to think on their own without me telling them what to think. I know we had classes about inquiry but I never knew how that would be especially with some of these kids that did not want to be there. I found that if you gave them an opportunity to think for themselves, they are a lot smarter than they think, and they can do it. I think it makes it more interesting for them to learn too.” (Sal)</td>
</tr>
<tr>
<td><strong>Science Content</strong></td>
<td>“I always saw content as very important, but there is a real need for a teacher to recognize other aspects. I do not think that I recognized this as much as I should have. [It is important] to model appropriate behavior, good speech, formal language...giving kids a chance to work with cooperation skills and things like that are just as important as the content that they are getting.” (Feran)</td>
</tr>
<tr>
<td><strong>Professional Aspirations</strong></td>
<td>“My biggest success was that I realized that this [teaching] is what I want to do. That was the biggest accomplishment that I have walking away. You have ideas and beliefs, but you don’t really know. After 10 weeks, I really enjoyed it.” (Neil)</td>
</tr>
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</table>
Ideal Teaching

The final theme is based on participant reflections on science teaching and learning under the best possible circumstances. I specifically asked students to consider what science teaching should be like in an ideal setting. All of the participants, with one notable exception that will be described later, discussed ideas consistent with reform-based pedagogies including inquiry, group work, student-centeredness, and hands-on/minds-on involvement. Keisha’s comment below was representative of most of her colleagues:

“[Science teaching should be characterized by] a lot of hands-on learning and student-led activities. I like for students to really experience something so they can really understand it better. I think it should include incorporations of things that are really hands-on or really interesting and different ways of presenting material.”

This result was not surprising because reform-based pedagogies were the central theme of the methods courses that the students completed. However, these positive appraisals of reform-based pedagogies in ideal settings were invariably followed by declarations of how difficult achieving these goals can be in actual classrooms. The overriding message was, “Reform based teaching is a great idea, BUT it is very hard to accomplish because…” Impediments identified by the participants included a lack of resources and equipment, time limitations, concepts were not amenable to reform-based approaches, students were unprepared, and students were too grade-driven. Table 5 presents a series of participant quotes which describe these impediments. I found it interesting that some student teachers declared their students under-prepared to engage in student-centered approaches; and yet, others felt that their advanced students, who presumably had the requisite skills, were too concerned with external pressures such as grades to make effective use of these approaches. The underlying theme was that regardless of the circumstances, reform-based teaching was very difficult to achieve.
Table 5
Taxonomy of Impediments to Reform-Based Teaching

<table>
<thead>
<tr>
<th>Impediment</th>
<th>Exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Resources</td>
<td>“When I was teaching, there were a lot of experiments that I wanted to do but I could not because we did not have the resources or the equipment.” (Sal)</td>
</tr>
<tr>
<td>Time Limitations</td>
<td>“There was definitely hands-on work [taking place in the classroom] and that was good, but I feel like there should be more student inquiry in the ideal situation…There was so much to cover and trying to cover it all is impossible, so time was certainly a factor.” (Steven)</td>
</tr>
<tr>
<td>Inappropriate Concepts</td>
<td>“I would say that [ideal teaching should involve] 75% inquiry lessons giving students opportunities to figure things out. However, I found that in chemistry, it is pretty hard to do because there are some basic concepts that students need to know. Now I think [that inquiry could be used] in advanced classes, like a second year chemistry class, when you are not trying to learn how atoms work and how electrons move. You can’t see it [basic chemistry concepts] and it [inquiry] is really hard to do.” (Oscar)</td>
</tr>
<tr>
<td>Unprepared Students</td>
<td>“Students are not used to thinking in terms of science or critically or things like that. They expect answers to be handed to them and they do not like it when there’s no right or wrong answer…I think that you really have to take time to get [students] to step by step think on their own. Like with inquiry, it still has to be very, very, very guided at the beginning.” (Tara)</td>
</tr>
<tr>
<td>Grade Driven Students</td>
<td>“When teaching chemistry, the students are very grade oriented and they want to get a good grade—that is the goal. Most of them are college-bound. If you teach chemistry differently [as in a reform-based approach], the students just are not—the student just are not as creative or willing to take risks because they’re concerned about grades.” (Vicki)</td>
</tr>
</tbody>
</table>

One participant had a markedly different perspective on ideal teaching and learning.

Irvine felt that under ideal circumstances, middle and high school science instruction should model the university approach. Teachers should give extended lectures and periodically coordinate associated labs. Irvine presented an interesting paradox in that he seemed to suggest that this approach did not necessarily best serve the needs of his students, but remained decidedly in favor of it. The following exchange highlights this pattern:
Irvine: In an ideal world, science teaching should look like the way it does at a university. It is in-depth lectures to teach content so that you know what you are doing coupled with laboratory experience.

Interviewer: How have your ideas about teaching changed?

Irvine: You cannot teach all kids the same. The “everyone gets the same education” ideal that a lot of people preach is impossible…

Interviewer: How do you square the notion of individual needs and the picture of the ideal classroom that you just gave me?

Irvine: If you’re going to do it that way, you’re going to wind up losing a lot of kids. I will admit that from the start in my ideal model.

Ironically, as Irvine’s instructor, I felt much the same way towards him as he had felt towards his students. Just as some of Irvine’s students did not “get” the science content he was trying to teach, Irvine did not seem to “get” the approach to teaching that I was trying to encourage. It is also interesting to note that Irvine openly discussed his desire to pursue an advanced degree in a science content field and eventually teach at the college level. These future plans may have contributed to the tenacity of his views even when he admittedly encountered difficulty with his teaching style.

Implications for Science Teacher Education

This research builds a phenomenological account of student teaching based on the experiences of science PST with the aim of informing science teacher education. The qualitative methods and sample selection preclude generalization of results, but the themes which emerged with these particular participants may be helpful to consider in the design and modification of science teacher preparation programs. This study focused on preservice science teachers, but many of the implications are not necessarily specific to science teacher education. It is likely that preservice teachers in other areas experience similar issues and have
similar concerns as those expressed in this study. Wherever appropriate, implications specific to science teacher preparation will be discussed.

An idea that surfaced in multiple areas of the taxonomy was the role of cooperating teachers. On one hand, many participants discussed the importance of certain characteristics and actions of their cooperating teachers in terms of their positive effects on the student teaching experience; whereas, others struggled with cooperating teachers who seemed unengaged and/or unable to provide critical feedback. This suggests that teacher preparation programs may need to provide support not just to their PST but also to the cooperating teachers. It seems likely that some participants in this study would have benefited if their cooperating teachers had been trained in how to effectively support student teachers. Pertinent topics might include how to provide critical feedback, how to negotiate classroom control, and the significance of encouragement. Better communication between cooperating teachers and university educators may also help alleviate some of the potential conflicts between the goals of these parties with respect to student teacher outcomes. In the context of science education, in particular, collaborations among university and classroom educators could help better define the kinds of inquiry opportunities student teachers could reasonably attempt.

Several issues emerged as areas of need in preservice education programs. These issues were situated across several themes (i.e., challenges, successes, and supports), but all directed attention to potential components of PST training. As in most appraisals of beginning teacher concerns (e.g., Kagan, 1992; Wideen et al., 1998) classroom management was a significant issue. However, this study was interesting in that several students discussed the fact that they had heard about successful management strategies, but did not want to use these approaches. Their preferences for more relaxed styles created problems and despite their original aversion to authoritative styles ended up resorting to these approaches. Classroom management may very well be an issue which PST must negotiate for themselves in actual
classroom contexts. Time management and the complexity of teaching were other issues which came up frequently. It might be that at least some aspects of these issues can only be truly experienced when one assumes responsibility of a classroom, but teacher prep programs could encourage students to develop specific strategies for time management as well as explicitly discuss complexities of schools and the teaching profession. Although time management is likely a concern for most preservice teachers, it may be particularly important for science teachers as they plan and prepare laboratories. Laboratory activities present planning challenges as in the acquisition and organization of resources as well as challenges for the management of class time. The most engaging, hands-on science activities always seem to run longer than a single class period allows.

An additional focus on working with special needs students would be another valued addition to science teacher education programs. Although all of the participants had taken a class in special education, they struggled to connect with special needs learners including students with learning disabilities and English as second language learners. Given the extent of this problem, in future classes I plan to supplement the information gained in the general course with more content specific suggestions and examples in the science methods courses. Demands for scientific literacy can present unique challenges for teachers working with special needs students. Textbooks typically contain hundreds of technical vocabulary which can make reading and comprehension difficult especially for students new to the English language or who have reading problems. Science education programs which direct preservice teacher attention to these factors and offer strategies for working with these students would be helpful.

Two other issues which support previous findings related to science teacher preparation arose in the success theme: content knowledge and reflective practice. While ample research supports the significance of both content knowledge (see, Zeidler, 2002) and
reflective practice (see, Loughran & Gunstone, 1997), this study revealed that student teachers themselves saw the merits of both a rich body of science content knowledge and the ability to critically reflect on one’s own teaching practices. Another recommendation for teacher education emerges from the support theme. The experiences of individuals who made efforts to become part of the broader school community were enhanced by those efforts. This kind of involvement could be built in as a programmatic expectation. It is true that adding requirements such as this contributes to an already full workload. The participants, who reported engaging in these activities on their own, did discuss constraints on their time but generally felt that the results of their involvement far outweighed the problems associated with time management.

In contrast to much of the research on teacher development (Adams & Krockover, 1997; Kagan, 1992; Kuzmic, 1994; Wideen et al., 1998), the participants in this study had generally favorable appraisals of the teacher preparation at least with respect to the science specific methods courses. While this conclusion may be considered suspect given my roles as both course instructor and researcher, it is not entirely unique within the field (Loughran, 1994). The fact that several students reported that they attempted inquiry learning activities and other approaches advocated in the methods course further supports the notion that the science education courses had positive effects. Admittedly, the extent to which participants implemented inquiry consistent with *NSES* is not addressed by these data, but based on the descriptions of instructional practices provided, it seems likely that the student teachers claiming success with inquiry were at least moving in the right direction (i.e., less emphasis on traditional approaches and more emphasis on student-centered approaches).

The participant views on teaching, particularly with respect to reform-based pedagogies, can be interpreted in at least two ways. Rust (1994) suggests that it is not uncommon for PST to maintain their idealistic views of teaching but that these views
typically change as they transition to full time professionals. This perspective suggests that the participants’ focus on inquiry and other student-centered pedagogies will be overwhelmed by the perceived impediments. While the participants certainly did cite several reasons why inquiry did not work in specific contexts, most still believed that it was an ideal approach to teaching science. Loughran (1994) provides a different, and slightly more optimistic interpretation:

The effect of preservice education is not so much “washed out” as repressed. Among the competing demands and complexities of teaching, the ideals once held in preservice education lose out in the real world of school. There is not so much an attitude shift (they still espouse to the notions of learning encountered in their preservice program) rather an acceptance of what is possible at this point in their careers. (p. 383)

Although I disagree with Wideen et al.’s (1998) conclusion that significant change cannot be affected by traditional teacher education programs, I strongly support their calls for an “ecological” approach to research in teacher education. They suggest that teacher education and its effects cannot be adequately understood by examining small aspects divorced from other contextual factors. The research presented herein examines a significant, yet limited component of science teacher preparation. Follow-up work is necessary particularly with respect to interactions among PST, cooperating teachers, university supervisors, and teacher educators. In addition, to gain more clarity on issues, such as how teachers’ ideals are affected by instruction as well as the profession, extended studies which can document the evolution and adaptation (Lederman & Gess-Newsome, 1991) of teacher ideas are needed. The current study contributes to this area as it documents the beginning of what will become a longitudinal cross-case study of science teachers as they transition from students to beginning teachers to veteran educators.
Oscar’s declaration of impending failure within the first three weeks of student teaching, recounted in the opening lines of this paper, might have aptly characterized many of his colleagues’ thoughts. It is likely that they were all focused on survival at the outset of the experience. However, it would be an oversimplification to suggest that the participants were just attempting to survive. They certainly struggled with challenges, but they also achieved successes and continued to learn about what it means to be a science teacher. Their stories are far from complete, but I can report that everyone survived and when asked about what they planned on doing in the next five years, all of the participants reported that they would be teaching.

*I’ll be teaching...because I just love it.* (Oscar)

Acknowledgements

I would like to thank Christine Lotter, Dana Zeidler and an anonymous reviewer for helpful comments on an earlier version of this manuscript.
Appendix A

1. Please describe the structure of your student teaching. What subject(s) did you teach, and what specific content did you cover? How did you and your cooperating teacher deal with student discipline? How much control did you have in terms of planning and implementing curricula, classroom procedures, etc.?
2. How did you fit in with the school community? Did you feel as though you were part of the school community or did you feel like an outsider? How did you relate to administrators, other teachers, and students?
3. What was challenging about your student teaching experience?
4. What kind of success did you have? What are you good at in terms of teaching? What areas are you still uncomfortable with and need to work on?
5. Do you feel prepared to run your own class? (YES: What lead to that preparedness?) (NO: In what ways are you unprepared?)
6. How would you characterize your teaching? Provide specific examples to support this characterization.
7. In an ideal world what should science teaching look like? How did your student teaching differ from this ideal?
8. How have your ideas about teaching changed over the period of your student teaching?
9. Where do you see yourself professionally in 5 years? Where do you see yourself professionally in the distant future (15-20 years)?

Bibliography


WHAT ARE THEY THINKING? THE DEVELOPMENT AND USE OF AN INSTRUMENT THAT IDENTIFIES COMMON SCIENCE MISCONCEPTIONS

Mary Stein, Oakland University
Charles R. Barman, Indiana University Purdue University Indianapolis

Abstract

The Purpose of this study was to develop an easily administered instrument that will help identify commonly held science misconceptions. The resultant product is a 47 item computer-based instrument, called the Science Belief Test, which targets topics in chemistry, physics, biology, earth science, and astronomy. Included in this paper is a description of the development of this instrument, its validity and reliability information, and recommendations about its future use in science education.

Introduction

Science teachers and educators are acutely aware that students often hold conceptions about scientific processes and beliefs that run counter to the beliefs and theories held by scientists. Fisher (1983) defined misconceptions as ideas that are at a variance with accepted views. Other, more neutral terms have also been suggested, such as alternative frameworks (Driver & Easley, 1978) and alternative conceptions (Hewson & Hewson, 1986). Similar to Odom and Barrow (1995), we use the term misconception to refer to students’ ideas that are different from the ones generally accepted by scientists. A significant amount of research has indicated that most people develop ideas about a variety of science topics before beginning formal science education and that these ideas tend to remain persistent despite efforts to teach scientifically accepted theories and concepts (Black & Lucas, 1993; Driver, Guesne, & Tiberghien, 1985; Driver, Leach, Millar & Scott, 1996; Osborne & Freyberg, 1985).

Another level of concern regarding science misconceptions deals with preservice and inservice teachers. Schoon (1995) suggested that many misconceptions originate in the classroom and that teachers cannot be expected to help children with alternative conceptions if they hold these alternative conceptions themselves. In a study of 122
preservice elementary teachers, he found that many had the same misconceptions that were held by students. In his study of alternative conceptions in earth and space science Sadler (1987) found that students “overwhelmingly” attributed the origin of their astronomy alternative conceptions to schooling. Schoon (1995) showed similar results with students indicating that many of the misconceptions had been taught to them.

The purpose of this study was to develop an easily administered instrument that will help researchers, science educators, and science teachers understand more about commonly held, existing scientific misconceptions. This instrument may help uncover existing misconceptions or alternative conceptions involving a wide range of science topics. This study involves two major components: (1) a description of the development of the Science Beliefs instrument, and (2) results when this instrument was administered during different stages of development.

The Relation of this Work to Other Efforts

Research on students’ beliefs and alternative conceptions they may hold has a long history and continues to be of great interest. A variety of methods have been used to elicit student ideas and these have been widely reported in the literature. Many of these methods are not feasible in terms of the time and effort for use in existing science classrooms. Moreover, many of the studies focus on specific science topics rather than on a broad range of science conceptions. Haslam and Treagust (1987) noted that individual student interviews are often a useful way for researchers to identify students’ misconceptions in science, however this methodology may not be as useful to teachers (Peterson, Treagust, Garnett, 1989; Fensham, Garrard, & West, 1981). Not only are methods for eliciting students’ beliefs often cumbersome for teachers, they may also fail to be useful to the students as a means for thinking about their own ideas, the reasons for those ideas, and how their ideas may change as a result of instruction. Odom and Barrow (1995) have advocated a need to develop paper and
pencil tests to help classroom teachers diagnose misconceptions. In keeping with the concerns related to the difficulty of conducting personal interviews as well as many other forms of data collection, the authors have developed an electronic instrument, the *Science Beliefs* quiz, which aids in revealing science misconceptions.

A thorough review of research related to the development of paper and pencil instruments used to determine misconceptions was undertaken. As noted above, many researchers indicated that there was a need for instruments that can be easily administered and used by classroom teachers. Although many of the developed instruments used a multiple choice format, one of the main problems with this format is that it is difficult to develop alternative responses that reflect the full range of students’ beliefs, including misconceptions, about a particular idea. Because the reason for administering the instrument is to uncover prevalent misconceptions, along with potential reasons for these misconceptions, the authors decided to use a two-tier instrument. The first tier consists of statements with a true/false response and the second tier asks students to provide written explanations to support the true/false response for each item. This format would have practical classroom implications. It would help the teacher to determine the extent to which a particular misconception is held by students, but also provides a mechanism for determining students’ underlying ideas. It would help teachers understand when students are selecting the “right” answer, but for the wrong reason(s) or, alternatively, the “wrong” answer but with a justified explanation.

**Development of the Instrument**

An initial subset of 23 items, all of which were derived from items used in previous studies, was converted into a true/false item format. This subset was administered to 112 preservice teachers during the first week of a semester-long science content course during the winter, 2004 semester. The purpose of this administration was to:
(1) ascertain sentence structure and clarity problems with each item that might allow for incorrect responses because of the way the item is phrased;

(2) determine whether the two tier design (true/false with explanation) was effective in discovering common student misconceptions;

(3) provide information about misconceptions that were prevalent within this sample of preservice teachers.

The vast majority of preservice teachers in this sample provided written explanations with their responses. These explanations helped the researchers to determine semantic changes for each item. Explanations that did not correspond with the selection of a true/false response were especially helpful.

With encouraging results from the pilot test, the authors developed the full version of the Science Beliefs Test. Test development involved four components: (1) defining the content of the test, (2) obtaining information about students’ misconceptions and test items previously developed, (3) developing the instrument using declarative statements based on previous instruments and standards, and (4) establishing content validity and reliability. Based on results from the pilot test, items in this subset were then revised and additional items were added to create a 48 item instrument that targeted student beliefs in chemistry, physics, biology, earth science, and astronomy. Many of these items were adapted from items constructed in previous studies on student misconceptions. Additionally, items were also created from statements contained within the content standards of the National Science Education Standards (National Research Council, 1996). After appropriate items were selected and/or developed, a panel of experts was used to determine the content validity.

The pilot instrument was administered to 110 preservice elementary teachers during the first week of instruction of a general science content course during the spring 2004 semester. Because the instrument was administered during the first week of class, this
provided a measure of background knowledge rather than information learned in a particular course. The preservice teachers also indicated whether they had majored or minored in science. As a result of this administration, one question was omitted, and others were revised in an effort to make each statement as clear and understandable as possible. The resulting 47 item instrument (see appendix) was then put online to test the online data collection process (see https://www2.oakland.edu/secure/sbquiz).

Description of the Science Beliefs Instrument

The first online page is a consent form – participants may respond to the questionnaire whether or not they provide consent to use the data for research purposes. If consent is given, the data is collected. If not, then the respondent can either quit responding, or can respond to each item, but the program will not collect these responses. For those respondents choosing to participate in the study, two questions are asked that will further determine whether the data should be collected: (1) whether the subject has responded to this instrument previously, and (2) whether the respondent is receiving help while answering the questions. If there is an affirmative response to either of these questions, then data for that subject is not collected. Respondents also provide demographic and background information so that comparisons among different groups (e.g., science majors vs. non-science majors and/or females vs. males) can be made. This method allows researchers to collect information about science beliefs from a wide range of subjects with different backgrounds. It will also allow those who are interested in the science beliefs of their students to easily access some of their existing ideas. Respondents provide answers and explanations to 47 items and the instrument concludes by showing each subject a list of each item, the respondent’s answer, and the correct answer. Each “correct” answer is highlighted in green and “incorrect” answers are highlighted in pink. An overall correct percentage is also calculated.
It should be noted that for many of the items, there are ways of thinking about the declarative statement that would make an “incorrect” answer “correct.” This is one reason that the opportunity to include an explanation that corresponds with the respondent’s answer is so important. The authors continue to work to clarify each item, however there will always be exceptions and ways to think about science that are valid alternatives to the “correct” answers provided.

Reliability and Validity

Analysis of the instrument with respect to its reliability and validity is ongoing. As discussed previously, many of the items from the instrument were developed for use with other instruments that targeted science misconceptions (see Table 1). The content validity of many of these items had already been established. A number of the items were direct statements found within the *National Science Education Standards* (National Research Council, 1996) and the content of this document was also established by a panel of expert reviewers. Additionally, the instrument has been through several iterations of development, during which respondents provided written explanations that detailed their understandings of the items. Through this process, it became evident when an item needed to be revised to enhance its validity. For example, item 14 originally stated, “When a book is at rest on a table (not moving), there are no forces acting on it.” While analyzing subjects’ responses during the pilot study, the vast majority responded “False” but provided the explanation that gravity was acting on the book. Through this item, researchers sought to glean information about understandings of balanced forces. Thus, the item was revised to its present form: “When a book is at rest on a table (not moving), other than the force of gravity, there are no other forces acting on it.” Many of the items went through similar types of revisions in an effort to enhance the validity of the instrument.
Reliability was investigated on a number of levels. For example, when considering only True/False responses, the internal consistency (Kuder-Richardson, KR-21) of the instrument is 0.77. A test-retest administration of the True/False items was used as further evidence of reliability. Items were administered and re-administered to 30 students within a two week interval. No instruction about the science topics was presented during this time. The test-retest reliability coefficient for this procedure was 0.776, which Campbell, et.,al., (1999) consider a moderate reliability estimate.

Another component of the reliability of the instrument is the extent to which the explanations provided by the respondents “match” the true/false answers. With respect to the explanations provided, an independent rater with expertise in science education was given a random set of thirty explanations for each item and asked to match them with the appropriate true or false response. That is, when reading only the explanation for a particular item, to what extent could the rater predict whether the subject had responded “True” or “False” to this item? The expert rater averaged over 90% correct matches between the explanations and each true/false item.

Conclusion and Next Steps

The Science Beliefs instrument appears to be a good instructional tool for those science educators who are interested in uncovering students’ beliefs about specific areas in science. The instrument will likely undergo continuous revision as items are clarified and added. Subsets of items in each science area (e.g., biology, chemistry, physics) will also be made available to science educators in those areas. Answers and explanations from various groups will be compared to determine the extent to which specific beliefs are held. These comparisons will include determining the extent to which differences occur between: (1) males and females; (2) science and non-science majors; (3) grade level groups; and (4) number of years of high school science taken as a student.
It appears that as a responder proceeds through the 47-item instrument, the number of explanations and the extent to which ideas are described is lessened. Responders may become fatigued with explaining their thoughts in this format. By dividing the instrument into relevant subsets with less items, the number and depth of explanations may increase.

In addition to adult responders, many of the items included in the *Science Beliefs* instrument may be useful to teachers of science at the elementary, middle, and high school levels. Preservice and inservice teachers of science may not only use these items to uncover the beliefs held by their students, but they may also uncover some existing misconceptions they personally hold. When this happens, it is more likely that the misconceptions held by teachers will not be transferred to their students through instruction.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item</th>
<th>Science Area</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The only ingredients that plants need to grow are: water, sunlight, and nutrients.</td>
<td>Biology</td>
<td>Annenberg/CPB Minds of Our Own</td>
</tr>
<tr>
<td>3</td>
<td>The only factors that are necessary for a plant seed to germinate (sprout) are water and a certain temperature range.</td>
<td>Biology</td>
<td>Barman, Stein, Barman, McNair, 2003</td>
</tr>
<tr>
<td>4</td>
<td>In order for a plant to grow, you need to provide the plant with fertilizer.</td>
<td>Biology</td>
<td>Barman, Stein, Barman, McNair, 2003</td>
</tr>
<tr>
<td>5</td>
<td>All animals depend on plants.</td>
<td>Biology</td>
<td>NSES</td>
</tr>
<tr>
<td>6</td>
<td>The arrows of a food chain symbolize the transfer of energy from one organism to another. (e.g., grass -&gt; mouse -&gt; snake -&gt; hawk).</td>
<td>Biology</td>
<td>Barman &amp; Mayer, 1994</td>
</tr>
<tr>
<td>7</td>
<td>If the producers (plants) disappeared from Earth, organisms that prey on other organisms for food (carnivores) would only be slightly affected.</td>
<td>Biology</td>
<td>Barman &amp; Mayer, 1994</td>
</tr>
</tbody>
</table>
Humans, dogs, fish, worms, and insects are all considered to be animals.

Organisms that possess locomotive structures (e.g., movement capabilities) and are able to reproduce are classified as animals.

All organisms are composed of cells.

Reproduction is a characteristic of all living systems.

Sexually produced offspring can be identical to either of their parents.

Extinction of species of organisms is common.

When a book is at rest on a table (not moving), other than the force of gravity, there are no other forces acting on it.

An astronaut is standing on the moon with a baseball in her/his hand. When the baseball is released, it will fall to the moon’s surface.

When two spheres that are the same size, have similar surfaces, but have unequal masses, for example, one made of wood and one made of lead (greater mass), are dropped from the same height above the ground, the more massive sphere (e.g., lead sphere) will hit the floor first.

When two spheres that are the same size, have similar surfaces and other characteristics, but with unequal masses, are dropped from the same height above the ground, the more massive sphere will hit with greater force.

A force is needed to change the motion of an object.

It is possible to light a flashlight bulb with just one wire and one battery and no other equipment.

We (humans) need light in order to see.

<table>
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<th>Science Area</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>An astronaut is standing on the moon with a baseball in her/his hand. When the baseball is released, it will fall to the moon’s surface.</td>
<td>Physics</td>
<td>Watts &amp; Zylbersztajn, 1981</td>
</tr>
<tr>
<td>16</td>
<td>When two spheres that are the same size, have similar surfaces, but have unequal masses, for example, one made of wood and one made of lead (greater mass), are dropped from the same height above the ground, the more massive sphere (e.g., lead sphere) will hit the floor first.</td>
<td>Physics</td>
<td>Zeilik &amp; Bisard, 2000</td>
</tr>
<tr>
<td>17</td>
<td>When two spheres that are the same size, have similar surfaces and other characteristics, but with unequal masses, are dropped from the same height above the ground, the more massive sphere will hit with greater force.</td>
<td>Physics</td>
<td>Zeilik &amp; Bisard, 2000</td>
</tr>
<tr>
<td>18</td>
<td>A force is needed to change the motion of an object.</td>
<td>Physics</td>
<td>NSES</td>
</tr>
<tr>
<td>19</td>
<td>It is possible to light a flashlight bulb with just one wire and one battery and no other equipment.</td>
<td>Physics</td>
<td>Annenberg/CPB Minds of Our Own</td>
</tr>
<tr>
<td>20</td>
<td>We (humans) need light in order to see.</td>
<td>Physics/Biology</td>
<td>Annenberg/CPB Minds of Our Own</td>
</tr>
</tbody>
</table>
21 If you see your head and shoulders in a mirror, with the mirror mounted securely and flat against the wall, and you wanted to see more of yourself (for example, your belt), you should back straight away from the mirror.

22 The velocity of a radio wave and a visible light wave is the same.

23 The total energy in the universe is constantly changing.

24 Most things in our universe tend to become more organized and more orderly over time.

25 Heat flows from warmer objects to cooler ones until both reach the same temperature.

26 A ball made of solid steel will not float. However, a boat made of steel floats because the steel is made less dense because of the way the boat is shaped.

Table 1. (continued)

<table>
<thead>
<tr>
<th>Item Number</th>
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<th>Science Area</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Under normal temperature and pressure conditions, all particles, such as atoms or molecules, are in constant motion.</td>
<td>Chemistry</td>
<td>Odom &amp; Barrow, 1995</td>
</tr>
<tr>
<td>28</td>
<td>An increase in temperature corresponds to an increase in the motion of particles.</td>
<td>Chemistry</td>
<td>Odom &amp; Barrow, 1995</td>
</tr>
<tr>
<td>29</td>
<td>If a small amount of sugar is added to a closed container of water and allowed to sit for a long period of time (e.g., a week or longer) without stirring, the sugar molecules will be more concentrated at the bottom of the container.</td>
<td>Chemistry</td>
<td>Odom &amp; Barrow, 1995</td>
</tr>
<tr>
<td>30</td>
<td>The bubbles in boiling water consist primarily of air.</td>
<td>Chemistry</td>
<td>Osborne &amp; Freyberg, 1985</td>
</tr>
<tr>
<td>31</td>
<td>Two containers with equal amounts of clear water are at two different temperatures. Equal amounts of green dye are added to each container. The dye will mix with the warmer water faster.</td>
<td>Chemistry</td>
<td>Odom &amp; Barrow, 1995</td>
</tr>
<tr>
<td>32</td>
<td>When a chemical reaction occurs, the total mass of the resulting products can be less than or greater than the original mass of the reactants depending on the type of chemical reaction that took place.</td>
<td>Chemistry</td>
<td>NSES</td>
</tr>
</tbody>
</table>
On a hot, humid day you place a cold glass of lemonade on the table. The droplets of water you notice forming on the outside of the glass are due primarily to condensation of water vapor from the surrounding air.

As one goes higher into the atmosphere (for example, climbing a mountain), the atmospheric pressure decreases.

A baseball hit with the same force will travel farther on a humid day as opposed to a dry day.

A visible cloud in the sky consists primarily of water vapor.

Approximately 97% of the earth’s water is found in the oceans.

Table 1. (continued)

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<th>Science Area</th>
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</thead>
<tbody>
<tr>
<td>38</td>
<td>Molten earth material (magma) that produces such features as volcanoes comes from the middle mantle (about half way between the Earth’s center and surface).</td>
<td>Earth Science</td>
<td>Schoon, 1995</td>
</tr>
<tr>
<td>39</td>
<td>It is unlikely that Chicago could experience a major earthquake in the next 500 years.</td>
<td>Earth Science</td>
<td>Schoon, 1995</td>
</tr>
<tr>
<td>40</td>
<td>One type of rock, such as a igneous rock, can be transformed into another type of rock, such as a sedimentary rock.</td>
<td>Earth Science</td>
<td>NSES</td>
</tr>
<tr>
<td>41</td>
<td>From our homes in the United States, there is no date or time when the sun is directly overhead.</td>
<td>Astronomy</td>
<td>Schoon, 1995</td>
</tr>
<tr>
<td></td>
<td>Day and night are caused because the earth spins on its axis.</td>
<td>Astronomy</td>
<td>Schoon, 1995</td>
</tr>
<tr>
<td>43</td>
<td>We see phases of the moon because the moon moves into the earth’s shadow.</td>
<td>Astronomy</td>
<td>Schoon, 1995</td>
</tr>
<tr>
<td>44</td>
<td>In the northern hemisphere, the earth is closer to the sun in the summer.</td>
<td>Astronomy</td>
<td>Schoon, 1995</td>
</tr>
<tr>
<td>45</td>
<td>When people in North America view a full moon, people who live in Australia would see a different phase.</td>
<td>Astronomy</td>
<td>Schoon, 1995</td>
</tr>
<tr>
<td>46</td>
<td>The reason we experience seasons is because the distance between the earth and sun changes.</td>
<td>Astronomy</td>
<td>Trumper, 2001</td>
</tr>
</tbody>
</table>
The longest daylight period in Australia occurs in December.

References


From Vaz, Carola, Neto.
THERE IS NO WORD FOR SCIENCE: TEACHING SCIENCE AT A TRIBAL INSTITUTION

Peggy J. Tilgner, Sinte Gleska University

Abstract

How does one teach science in a manner that recognizes the culture while maintaining the integrity of a Western science curriculum? Native American students learn science, as well as about the rest of the world, by recognizing relationships and changes, observing and evaluating context and using a circular view of time. A course developed by pairing a Lakota Studies class on plants, animals, and land with an integrated science class attempts to bridge the gap between Western science tradition and knowledge valued by the Lakota culture.

Introduction

How does one teach science in a culture that has no word for science? How does one teach science when the entire world view of the people of this culture is science, philosophy, religion, spirituality all rolled into one?

How science operates in today’s world is based largely on a logical-positivist philosophy of science which was developed primarily by wealthy western European males--German, Italian, French, and British gentlemen--who pursued science first as an avocation, and later as a vocation. The science that is taught in our schools today is a product of that philosophy. It is the science of Galileo, Newton, Pasteur, Priestly, Dalton, Lavoisier, Avogadro, Kepler, Brahe, Einstein, Darwin, Linnaeus, Watson, and Crick. It is not the science of the ancient Chinese dynasties, the North African Moors, or the Mayans of Central America. It is not the science of women or native peoples.

Science has a long tradition of marginalization of women and nontraditional voices. Norman (1998) argues that these individuals could bring new perspectives on the study of nature, but their findings are continually excluded because institutionalized science does not claim them as full members. Science, because of its claim of objectivity, considers genuine scientific claims to be beyond the contingencies of culture and history. W.E.B. DuBois and Frederick Douglass, two noted African-Americans, were able to show fallacies in the
arguments of scientists, but their findings were marginalized because of their cultural background. Norman contends that the scientific establishment has remained hostile to suggestions that the complex relationship between science and culture be examined (Norman, 1998).

For too many students, walking into the science classroom is like walking into a dark, scary cave. As teachers, we need to engage in culturally relevant pedagogy that is committed to both collective and individual empowerment. This pedagogy is based on helping students develop and maintain their cultural identities. A culturally relevant pedagogy helps students develop a critical consciousness which in turn will allow them to challenge the status quo with their scientific knowledge (Atwater & Brown, 1999).

Native American science

Consider the example of working with Native American students. They learn science by identifying relationships and changes, observing and evaluating context and using a circular view of time. What is valued knowledge to them is knowledge that draws them closer to a spirit of harmony (Atwater & Brown, 1999). What do many science teachers do—teach science by analyzing natural phenomena in a lab setting, out of their natural contexts. This form of instruction makes the Native American students feel like outsiders, guests in their own classrooms (Allen & Crawley, 1997).

Even with the blurred boundaries between disciplines and acceptance of other approaches to practicing science, there still remain distinctly different reasons for “doing science.” Indigenous cultures value survival over subduing nature; coexistence with the mysteries of nature over attempting to explain away these mysteries; and a search for an intimate relationship with nature over decontextualized objectivity (Cajete, 1999). Rather than looking at science from a distant abstract position, indigenous people understand the world in terms of how self relates to others including both the animate and inanimate parts of the world (Deloria, 2001; Kozoll & Osborne, 2004).
For example, indigenous communities are great resources of local ecological information held by individuals who practice a traditional lifestyle. Science educators ignore that ecological knowledge even though it is long-term, because it is observational and often undocumented. Western science demands that knowledge be accessible and available for public scrutiny. Indigenous people think that coming to know refers to the understanding there is a responsibility associated with any knowledge. Some knowledge is inaccessible until the learner demonstrates preparedness (Sutherland, 1999).

Gregory Cajete (1999), a Native American science educator, has developed and practiced an integrated approach to teaching science for over 25 years. His development of integrated thematic units incorporates many brain compatible principles of instruction including absence of threat, meaningful content, choices, adequate time, enriched environment, collaboration, immediate feedback, and mastery. This idea of a holistic approach to science is supported by the research done by Oscar Kawagley (1995) with Native Alaskans.

Nancy Allen (1997) has researched the use of indigenous models for science and culture curriculum development. She indicates that it is important that the culture is balanced with what students need to know off the reservation. Such a curriculum may be culturally sensitive, culturally enriched, or culturally immersed depending on the needs of the school and community.

Course description
The initial idea for the course described in this paper was the result of a presentation by and follow-up conversations with the granddaughter of Black Elk. A book comparing Native American myths and stories with geological information as well as conversations with various instructors in the Lakota Studies Department at Sinte Gleska University led to the actual development of the current course. Content from several courses offered in the Lakota Studies department provided the primary instructor of an integrated science course some of
the cultural knowledge that was incorporated into the class. Native American students in the class also contributed to the cultural knowledge base. Other knowledge was gleaned from resources available in the extensive Native American library holdings at the university.

The class is entitled “Integrated Science I” and focuses on searching for and identifying patterns in the natural world. Science content for this particular course is mainly ecology and astronomy. The primary text for this course is *Native Science* by Greg Cajete, which provides the students with some philosophical understanding behind the approach used in the course. Supplemental materials include instructor-written descriptions of Lakota plant, animal, and star knowledge as well as selected resources taken from various websites. Field guides are used extensively to help students locate the organism or constellation to be studied. Elder knowledge of natural phenomena is an integral part of the content and is primarily shared by students who have interviewed family members.

Students in the course are primarily elementary education majors. Many profess that science is not a favorite subject. Most have taken only the bare minimum in high school--biology and general science. (Younger students have had a third course, usually chemistry). Approximately one-half of the students who end up in the course have had to take one or more of the basic science courses offered to prepare our nontraditional students for college-level work. Therefore, one of the first tasks in the course is to convince students that they can “do science” and that they will enjoy it.

The classes are small, typically between ten and fifteen students who often know each other from other courses, so collaborative work is easy to implement. Early activities are based on activities found in *Project WILD, Project WILD Aquatic*, and *Project Learning Tree* and introduce students to basic ecological concepts such as ecosystems, populations, and adaptations. Even though many of the students’ ancestors were careful observers of their
world, these students are much more attuned to television and the internet and need to be taught how to make careful and complete observations.

We are fortunate that our new campus is bordered by a small lake with both grassland and riparian habitat nearby. It is here where we begin the task of learning how to carefully observe by choosing a plant and drawing it and writing a complete description. Once students have completed this activity, the instructor asks them twenty questions about their plant. Most have to return to the organism in order to find the answers because they really have not examined the specimen in depth. Based on the final description, students are asked to come up with a name for their organism. Lakota names of both plants and animals are highly descriptive as were some of the students’ English names. Students are then taught how to use plant identification keys in order to find both the scientific and common name of the plant. Additional research is done to find out what uses were made of the plant. When possible, students also interviewed local elders to find out traditional uses of the plants.

Once the group is capable of identifying 10-12 traditionally important plants, we travel to various sites on the reservation to look for these plants and to do a population count in a selected area. This is part of a larger project being done under both NSF and NASA grants to “map” the reservation and compare current data with historical records. The students report in their course evaluations that this is a valuable exercise they are contributing to the local knowledge base, and they are validating the stories they have heard their grandmothers and grandfathers tell.

As a science instructor, I am particularly pleased because the students now begin to raise all sorts of questions that I can help them answer. One of the questions we have investigated in the past two years is why many plants will not grow near the sage plants. Cultural stories talk about sage families and how they migrate. One of the instructors in the Lakota Studies department has a study area where students can observe the annual movement
of the “families” and note the change in the plants found surrounding the sage clumps. One student wondered if the oil in the leaves acted as a herbicide and tested it on radish seeds, which sprouted as well as some grass seed in the prairie soil used.

Some of the other questions have led to analysis of soils chemicals and measuring soil characteristics such as permeability and porosity. Other students have looked at the effects of the plants and animals found in a watershed on water quality, particularly nitrate and phosphate levels in surface and ground water. Students have raised questions about why some plant species are found only high on a hillside while other species can be found almost anywhere you look.

One of the tools that has been a valuable resource in helping students find answers to their questions is satellite imagery. Our university has an alliance with USGS and the EROS Data Center. We have access to thousands of aerial photos dating back to the early 1950s as well as the latest satellite imagery. Much of this data is currently contained in a geopresenter package called RezMapper that is relatively easy for the students to use. Students can look at the densities of plant material. They can also see the effects of prairie fires on vegetation density.

Semester-long observations are also made of sun position, moon position and phases, and weather conditions. While we have access to data from a computerized NOAA weather station, students are encouraged to look for connections between what they observe in the sky and what they sense, to predict future weather conditions. Family members who have been long-time sky watchers turn out to be as accurate at predicting as the most sophisticated weather data equipment. Students often come to class commenting on cloud types, wind direction shifts, and asking if I agree with their weather predictions.

The Lakota people have a well-developed star knowledge that serves as a departure point for a study of astronomy. Familiar constellations such as Orion, Cepheus, the Pleides,
and the Big Dipper are part of a racetrack of constellations that are prominent in Lakota folklore. Students learn to identify the important constellations and research the significance of each to the ceremonies that are part of the culture.

As with the plant and animal studies, the sky observations lead the students to raise all sorts of questions about the sun, moon, and planets. We do a number of NASA activities to help them develop an understanding of these celestial bodies and sky phenomena. Their knowledge is compared with the knowledge that has been passed down through oral tradition. Students soon realize that their ancestors were not primitive people but sophisticated observers who used stories to share the knowledge with others.

Implications for practice

When I began teaching this course 4 years ago, I was excited because I finally had the opportunity to use a thematic approach and cross discipline boundaries in a single science course. Water, patterns, and energy were themes around which the two courses were organized. However, I had a hard time breaking with the traditional reductionist approach to teaching science concepts. It wasn’t until I had taken a couple of courses from the Lakota Studies department and listened to the stories my students brought to class that I began to see that Lakota philosophy is a form of systems thinking. There is no separate word for science because what western thought terms “science” is simply part of a larger system of nature and human interaction with nature as viewed by indigenous people.

I am fortunate in this class to be able to use an inquiry approach to teaching. The classes are small and because of a number of funding initiatives, we have well-equipped science labs. The biggest problem is teaching the students to actively inquire instead of being passive recipients of knowledge. In addition to field work, the students engage in a variety of in-class activities that illustrate concepts as well as providing information to help answer their questions. Much of the work is collaborative in nature with the students and instructor.
engaging in instructional dialogue to make sense of the observations and data gathered both in the field and in the laboratory.

There are those who would argue that what I’m teaching is “watered down science”. (Sweeney, A. E., 2001). They say that using such an approach provides, at best, surface coverage of concepts. What we do in the integrated course certainly isn’t a microanalysis of a single discipline. However, I am constantly amazed at the detailed concept maps students are able to make that show how many different science concepts they have developed an understanding of as they search for answers to their questions. While some of the links show only a superficial understanding of a concept, many reveal a depth of understanding that most discipline-bound instructors would be pleased to see from their students.

Others would argue that it isn’t good science because some of the content comes from oral tradition and is not peer-reviewed research. While there is a good portion of accepted science content in the reading handouts, there are many “stories” from the culture that have been transcribed in the past 100 years that students also read. Since traditional education could be provided by anyone with knowledge, students are encouraged to visit with tribal elders to hear the traditional knowledge. That person did not have to be an certified teacher with an advanced degree in order to provide education (James, 2001).

The approach used in the integrated science sequence is based on constructivist philosophy. Students look for relationships among concepts that
The goals of this initiative are to foster synthesis and development of a holistic model which will require development of interdisciplinary courses focusing on relevant topics.

Another resource that was very enlightening for me and part of the catalyst to try incorporation of the culture in the science course is a book by Morton, a geologist, and Gawboy, an Ojibwa storyteller called *Talking Rocks: Geology and 10,000 years of Native American Tradition in the Lake Superior Region*.

Traditional educational processes were carefully constructed around mythology, history, observations of natural processes, plants, and animals, and the use of natural materials to make tools and implements. Teaching and learning were holistic and an integral part of everyday life. Culturally appropriate knowledge was gained through activity, observation, contemplation. People survived by learning to ask the right question, by making careful observations, and by memorizing data and incorporating that data in stores to explain natural phenomena (Kawagley, 1995). The knowledge from myths, collective thinking, experiential learning, and intuition are needed today to help students bridge the gap between western science and cultural knowledge. Paul de Hurd (1997) says that we need science education that speaks to human affairs and prepares students for involvement in them. For too long, Native American students have not had this kind of science education. For the most part, the science taught to Native Americans has followed the reductionist model that focuses on parts. I hope that the model described in this presentation will inspire others who teach Native American students, or students from non-Western cultures, to provide their students an opportunity to compare traditional knowledge with Western scientific knowledge.
I think my students sum it up best. “This class has opened my eyes to the different ways our people looked at the world compared to today’s Western belief” (student evaluation, 2003). “It is nice to have an instructor who is willing to learn from what students have to share and who expresses her appreciation for that sharing” (student evaluation, 2004).

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TEACHER/SCIENTIST PARTNERSHIPS AS PROFESSIONAL DEVELOPMENT: UNDERSTANDING HOW COLLABORATION CAN LEAD TO INQUIRY

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Abstract

Despite growing consensus regarding the value of inquiry-based teaching and learning, the implementation of such practices continues to be a challenge. Hurdles include state-mandated high-stakes exams, other time related constraints, teachers’ perceptions of their students’ expectations and abilities, and teachers’ fear of launching into the unknown. Through Cornell Science Inquiry Partnerships (CSIP), an NSF Graduate Teaching in K-12 Education (GK-12) program, science graduate students work intensively with secondary teachers to help them overcome obstacles to implementing inquiry-based learning, including original scientific research. CSIP fellows bring new science content and teaching strategies into secondary classrooms while simultaneously receiving feedback from teachers on ways to improve their lesson plans, classroom management strategies, and communication skills. The scaffolding provided through these partnerships and the associated CSIP learning community enables teachers to take increased risks in their classrooms. When fellows and teachers collaborate to facilitate student inquiry projects, together they deal with unexpected or unknown outcomes, address misconceptions, and determine how open-ended inquiry-based learning can best be used in specific classroom settings. This helps teachers overcome their initial hesitation and see the benefits that inquiry learning can produce in terms of motivation and achievement of students at a variety of grades and achievement levels.

Introduction and Theoretical Framework

Engaging K-12 students in inquiry-based learning is a cornerstone of current and long-standing efforts at science education reform (American Association for Advancement of Science, 1993; National Research Council, 1996, 2000). The National Science Education Standards call for “inquiry into authentic questions generated from student experiences [to be] the central strategy for teaching science” (National Research Council, 1996, p. 31). Learning is viewed in terms of processes though which students collaboratively construct shared meaning while working in teams, tackling real-world problems, and addressing questions for which no single correct answer exists. The overall goal is to help students gain skills they will
need to become lifelong learners who can access, analyze, and synthesize information and apply it to a diverse range of new situations and problems.

As defined by the Standards, inquiry is both a pedagogical strategy and a learning goal. Students engaged in inquiry-based learning construct their own knowledge by doing: they ask scientifically oriented questions, plan investigations, use appropriate tools and techniques to gather data, formulate explanations from appropriate evidence, evaluate their explanations in light of alternatives, and then communicate and justify their proposed explanations (National Research Council, 2000). In doing so, students not only learn content but also develop understanding of how scientists study the natural world. Through explicit and implicit instruction, they also learn about the nature of science, defined to include the values, beliefs, and assumptions that underlie the creation of scientific knowledge, in contrast with other ways of knowing about the natural world (Lederman, Wade, & Bell, 1998; McComas, Clough, & Almazora, 1998).

Despite growing consensus regarding the value of inquiry-based teaching, implementation of such practices continues to be a challenge for many teachers. One problem is confusion about what exactly is meant by “inquiry.” The various approaches to inquiry span a continuum with varying degrees of self-directed versus teacher- or curriculum-directed learning (National Research Council, 2000). Teachers exhibit a wide range of conceptions of inquiry, representing either approaches along the continuum or misconceptions about what is meant by this term. Some define inquiry as learning driven by questioning, but many think of it as any sort of hands-on activity. Not surprisingly, these varying conceptions and misconceptions shape the ways in which inquiry is or is not implemented in classrooms (Keys & Bryan, 2001; Llewellyn, 2001).

Another challenge to implementing inquiry-based learning is that many teachers view factual knowledge as the most important student outcome, achievable through repeated drill
Modeling their teaching on the way they were taught, teachers feel more comfortable relying on textbooks, lectures, and demonstration labs rather than facilitating inquiry-based experiences (Davis, 2003; Loucks-Horsley, Love, Stiles, Hewson, & Mundry, 2003). Even among teachers who profess interest in inquiry-based teaching and view science as a continuous process of discovery, many give greater priority in practice to transmitting facts than to enabling students to carry out their own investigations (Tobin & McRobbie, 1997).

Tobin and McRobbie (1996) define four cultural myths that contribute to teachers’ perception of science as a body of truths to be imparted to students. The transmission myth views the teacher as the principal source of knowledge to be delivered to students. The second myth relates to the need for efficiency, which translates into content coverage being considered more important than learning with understanding. This relates closely to the remaining two myths, which concern teachers’ perceived need to maintain the rigor of the curriculum and prepare students to succeed on examinations. Teachers feel pressured to maintain control of classroom learning so that content will be covered efficiently without time being wasted. Collectively, these four myths result in significant emphasis on low level learning, focusing on learning of facts and algorithms that will enable students to obtain correct answers on exams. Because these myths are shared by teachers and society alike, they support the status quo and hamper efforts at science education reform (Tobin & McRobbie, 1996). As high stakes exams become ever more prominent at the state and national levels, the pressure to prepare students for test-taking presents a formidable challenge to inquiry-based teaching. In New York State, where passing a Regents science exam has become a high school graduation requirement, test preparation is an overriding concern of high school science teachers (Veronesi & Voorst, 2000).
Perhaps the most challenging obstacle to inquiry is teachers’ reluctance to feel out of control of what is going on in their classroom (Uno, 1997). Teachers who have never conducted scientific research feel unprepared to lead students in formulating questions, designing experiments, and representing data – activities that are pedagogically risky but also central to inquiry-based learning (Kennedy, 1997; Singer, Marx, & Krajcik, 2000; Windschitl, 2003). Although grappling to understand the meaning of messy data or unexpected results provides rich opportunities for learning, teachers without research experience tend to be more comfortable with the traditional “cookbook lab” approach in which the outcome of laboratory experiences is predetermined and unexpected results are viewed as failures rather than as interesting scientific findings that can lead to further investigations (Amerine & Bilmes, 1990).

A critical question for science educators is how to provide professional development that will help teachers overcome the considerable challenges they face in implementing inquiry in their classrooms. Engaging students in truly open-ended inquiry requires a teacher to have appropriate pedagogical tools, confidence, an understanding of science in its social context, experiences with scientific inquiry, and agreement with the goals of reform-based science education standards (Avery & Carlsen, 2001; Barnett & Hodson, 2001).

**Research Context**

Over the past five years, the Cornell Science Inquiry Partnerships (CSIP) has provided fellowships to 44 Cornell graduate students through NSF’s Graduate Teaching Fellows in K-12 Education (GK-12) program. CSIP fellows, representing a wide range of science and engineering fields, spend ten hours per week teaching collaboratively with secondary teachers in classes ranging from remedial through advanced placement science. They spend an
additional five hours per week developing curriculum resources based on their expertise and
the interests and needs of their partner classes. CSIP teachers participate voluntarily because
of their interest in providing new experiences for their students and improving their ability to
teach using inquiry-based strategies.

One of the goals of CSIP is to help teachers gain familiarity and comfort in inquiry-
based teaching through working with fellows to develop and guide activities in which
students frame scientific questions and conduct activities to address these questions. In classes
with flexible curricula and teacher interest, fellows facilitate projects in which the teacher,
fellow, and students work together as co-researchers on genuine research endeavors. In
classes that are constrained by preparing students for standardized exams, fellows are more
likely to work with teachers to develop short-term projects aimed at developing students’
understandings of required concepts. The approaches used by CSIP fellows generally fall into
these categories:

- **Open-ended research**: an original experiment or series of experiments, monitoring
  projects, or other research designed and conducted by students.

- **Remodeled labs**: traditional labs and field activities that have been adapted by
  fellow/teacher teams to meet curriculum requirements through a more inquiry-
  based approach,

- **Nature of science lessons**: activities designed to lead to an understanding of how
  scientists study the natural world, and

- **Other**: new approaches to addressing required topics; interactive “meet-the-
  scientist” presentations about the fellows’ research; and “inquiry moments,” or
  spur-of-the-moment topics, insights, or questions introduced by fellows in
  response to opportunities that arise in the midst of regular classroom discussions
  and activities.
The goal of this study is to investigate ways in which collaborations between fellows and teachers have helped teachers overcome the significant hurdles to implementing inquiry-based learning in secondary level science classes. In particular, we focus on the following research questions:

1. What obstacles influence teachers’ receptivity to the implementation of open-ended student inquiry?
2. In what ways can partnerships with science graduate students help teachers overcome the obstacles to inquiry-based teaching?

Methods

These research questions were addressed using classroom observations, pre and post interviews with teachers, post interviews with fellows, focus group discussions with teachers and fellows, evaluation of fellows’ written curriculum resources, and evaluation of student work in class and at a student research congress held annually on the Cornell campus. Teacher interviews in the 2003-04 school year employed the Cognitive Clustering Model (Harwood & Hansen, 2004) to engage teachers in discussion of their conceptions of inquiry and its applicability in their teaching. In addition to providing post assessments of their conceptions of inquiry teaching, end-of-the-year interviews of teachers and fellows also explored the scientist/teacher relationships, the perceived nature and success of each fellow’s curriculum project, and the perceived impacts of CSIP on the teacher, fellow, and students.

Interviews and focus group discussions conducted in 2003-04 were transcribed in entirety and analyzed using Nvivo® software. In previous years, interviews were recorded and summarized. Content analysis was performed using a qualitative approach based on
grounded theory and constant comparative analysis (Glaser, 1969; Patton, 1990; A. L. Strauss, 1987). Using the research questions to guide the analysis, the data were coded using the pattern of open coding, axial coding, and selective coding advocated by Strauss and Corbin (1990).

The nature of scientist/teacher partnerships was examined through triangulation of data from interviews of fellows and teachers, classroom observations, and analysis of projects conducted by students and curriculum resources produced by fellows (Guba & Lincoln, 1983). A combination of qualitative and quantitative methods formed the basis for developing grounded interpretations of the data (Glaser, 1969; Guba & Lincoln, 1983; Scriven, 1983; Silverman, 2000). Classroom observations were performed using an ethnographic approach. Notes were taken throughout each visit to capture the trajectory of the lesson, teacher dialogue and actions, student dialogue, and other relevant information. Handouts and other materials related to the lesson were collected. Following each observation, the participating teacher and fellow were asked to send an email reflecting their impressions of the successes and challenges of the lesson.

Results and Discussion

Obstacles to Inquiry

CSIP teachers identified four major hurdles affecting their ability to incorporate inquiry teaching strategies into their classroom: (a) state-mandated curricula and the accompanying high-stakes final exams, (b) other time related constraints, (c) students’ expectations and abilities, and (d) teachers’ fear of launching into the unknown. These
constraints were articulated across the board, by new teachers and those with decades of experience in the classroom.

High Stakes Exams

Although CSIP teachers are self-selected for an interest in innovative teaching practices, many expressed concern about tension between teaching in ways that they consider to be best practices versus the need to cover a predetermined body of topics, concepts, and principles in order to prepare students for Regents final exams. (New York requires students to pass two Regents science courses and at least one Regents science exam in order to graduate.) Some teachers described the Regents exams as both the guiding framework for their course and the primary motivator in their teaching. For example, one said:

I think my role is to give kids opportunity to do [science] in a meaningful way that accomplishes my objective of getting them ready for the state exam at the end the year and a larger objective of opening career possibilities to them. I think it's my role to organize the body of knowledge in such a way that kids can master what they have to, but to also provide enough opportunities for hands-on and other activities that will excite their interests and kind of solidify the abstract concepts for them.

A natural outcome of the intense focus on Regents exams is the perception by teachers of their role being to help students master a particular body of knowledge. At times this translates into teaching strategies specifically designed for test preparation. One teacher described inquiry labs as extra labs that get used during the week or two before semester breaks so that anyone who was absent would not jeopardize their ability to do well on the Regents final exam. Another teacher said that she creates all of her tests with a format similar to the Regents in order to accustom her students to the type of multiple choice questions they would see on the exam. Conflicting ideas about effective teaching strategies are illustrated in this teacher’s reflection on the potential benefits and drawbacks of worksheets:
I've never been a worksheet sort of person, but I will say that I think that sometimes my students have not been as well prepared for Regent exams as if I'd had them do a worksheet. On the other hand my daughter went to a high school where kids did great on Regents exams and did all kinds of worksheets and didn't learn any kind of science.

Perhaps surprisingly, Regents exams dictate teaching even in classes in which the students are not at risk of failing:

You don't want to change – your classroom works, your kids are getting through the Regents exam. Why bother changing? You know, I've got 100% passing rate right now with the new Regents… All of us teachers at (our school) have had 100% passing rate for the last couple of years. Why do we want to change, why do you want to upset the basket?

Although teachers teaching elective courses have greater flexibility in implementing innovative teaching practices than those teaching Regents courses, they nonetheless face other hurdles to inquiry described below.

**Time Constraints**

Time constraints were cited by teachers as hurdles to implementing inquiry in elective courses as well as those with a tightly prescribed curriculum. One concern, brought up by several teachers, was that more class periods are needed for inquiry-based labs compared with traditional lab exercises. For example, one teacher explained that many of the labs he uses end up “not having much of an inquiry component to them” because inquiry requires more time and students may not come up with the correct results or interpretations:

…the biggest thing about inquiry is that it takes time to digress away from your expected outcome. So [for some of the] State labs that we're required to do, inquiry is not something that you want because you've got to have kids understand exactly the content of the lab and how you get from A, to B, to C.

A related concern brought up by two teachers was the idea that it takes too much time for students to “figure it out for themselves.” Both of these teachers had relatively naïve
conceptions of inquiry as a type of unstructured learning in which students discover scientific concepts and principles entirely on their own:

When they can figure it out for themselves, inquiry based, no question about it… but the time factor doesn't allow for that. You know, the discovery learning. Put a whole bunch of materials in front of the person and say, “Discover, figure out what you can about it, and then report back.”

A final time-related concern related to the teachers’ preparation time rather than time in class. Several teachers stated that they do not have sufficient time during the day to develop inquiry-based labs or activities for their courses. They argued that designing inquiry-based activities requires extra time which isn’t readily available. For example, one teacher mentioned that he currently teaches “five classes a day officially, six unofficially, and I have one half-hour of prep time.” He felt that one of the biggest things anyone could do to support teachers would be to give them more preparation time for their teaching, especially if the goal was to develop inquiry-based laboratories or activities.

**Student Expectations and Abilities**

Eleven of the fourteen teachers interviewed at the beginning of the 2003-04 academic year said that inquiry is a good idea but might not be practicable with their students. Interestingly, their concerns were related to students at both ends of the achievement scale. Some teachers referred to students who can’t handle the independence that an inquiry investigation entails, whereas others referred to students who are strong academically but become frustrated with inquiry because it breaks from their accustomed route to academic success.

One teacher summarized her feelings about the difficulty that some students have with inquiry learning by stating simply that “some students feel lost.” She mentioned that this feeling can be exacerbated when such a student is paired in a group with one or more other
students who have similar reactions to an inquiry environment. A similar sentiment was expressed by other teachers in terms of students needing to understand the basic elements of a scientific investigation before they can “do inquiry.” One teacher stated:

We're finding that you sure can't just jump into (inquiry), expect them to go through all the steps and have any clue. You have to start with a very simple, tiny little experiment and have them work their way up to more complicated things. This is just like some of the labs that are coming out of the state. They're definitely not something that you do right at the beginning of the year. They are inquiry things that they have to learn just how to go about. How to write a hypothesis, how to understand what are independent variables and dependent variables, and how you have to keep other variables the same. They have to have some concept of what you're doing before you can actually do an experiment.

Another teacher said that a mixture of teaching styles is necessary “…because there are kids that just can't handle [inquiry]. And there are kids that can't handle straight traditional learning either, so you have to give all students a little bit of something every week otherwise they will shut down.” A similar comment was made by another teacher who framed the issue in terms of flexibility. When asked whose flexibility she was referring to, she said:

The kids and teacher both. And it's sometimes hard for both to be flexible because you know this is new. Like I said, we do have a pretty good portion of kids who come from [a private school], and it's hard for them to be flexible you know. And some kids just have a hard time with (inquiry). That pushing them out of the box. So everybody has to be flexible.

Another concern expressed by teachers with regard to inquiry was that their students expect them to provide structure and guidance and wouldn’t be satisfied with a more open-ended form of learning. One teacher said:

I think there are a lot of students, particularly some of the brighter students, who want me to give them directions and they want to do it and they want to do it better than anybody else, and they want to get the right answer and they get very frustrated when I tell them, “Well, maybe that would work. Why don't you try it? You can always do it again if it doesn't work.” They're thinking, “Do it again? No, I did it right the first time.” So it's frustrating, but I think for those kids the experience is a really good lesson.
High-achieving students are adept at memorizing information and following directions to achieve high grades through traditional forms of assessment. Inquiry-based investigations can make these students uncomfortable because different types of learning are required. One teacher comments that some of her normally high-achieving students did not do as well as other students on inquiry projects:

It made them absolutely crazy. It’s kind of interesting. You'd think that the kids that got A's all their lives would be these great critical thinkers, but I found that that was the opposite, that some of my special ed kids were better at the critical thinking piece than my advanced kids.

Other teachers expressed similar concerns about students at any ability level. However, they also noted that students’ discomfort with inquiry-based labs can be a good experience:

Some kids want everything to be step-by-step. They want to be spoon-fed. And you know they are comfortable with that, and they don't like it to be fuzzy. So I don't think everybody will necessarily like inquiry-based. But will they benefit? Maybe it's good for them to see that the world is not always, you know, clear cut and perfect.

Several teachers with significant experience in inquiry-based teaching discussed the opposition they have faced from students when using inquiry strategies. For example, one said:

I did a lot more inquiry exploration in the middle school. They would look at me and they would say, “You are a horrible teacher because you're not telling us the answer,” and I'd say, “I don't care. You have to find out the answer.”... What I find probably even more with the high school kids is that they are kinda like, “Just tell us what you want us to know,” so it's a struggle.

Although the extent to which science teachers tend toward a didactic, teacher-centered style of teaching has been well documented (Bryan, 2003; Eick & Reed, 2002; Rop, 2002; Simmons et al., 1999; Squire, MaKinster, Barnett, Leuhmann, & Barab, 2003), the degree to which students believe that learning should be primarily a transmissive endeavor is less well
researched. Using an attitude questionnaire, Berg, et al. (2003) assessed college student perceptions of their own role and the role of their teacher in the context of an expository or open inquiry chemistry experiment. They found that some students defined good teaching in terms of presenting clear instructions, spelling out exactly what to do, and preparing students for the exam. The degree to which K-12 students have similar perspectives is a potential topic for future research.

Fear of the Unknown

Although fear of the unknown was not brought up by teachers in beginning-of-the-year interviews, those interviewed at the middle or end of each school year consistently have mentioned that working with fellows has helped them to overcome their reluctance to let students explore topics for which the outcome was not known. This finding applies to teachers of all types of courses, both with and without mandated curricula or high stakes final exams.

Of the four CSIP teaching approaches outlined in the Research Context section, open-ended research requires the greatest degree of willingness to relinquish control in order to accommodate open-ended learning. For teachers with no previous experience conducting scientific research, delving into projects with unknown outcomes requires a major leap of faith. After his class conducted a yearlong series of investigations under the guidance of a fellow, the teacher of an elective high school course reflected about this experience:

I couldn’t see the path ahead, which was scary but also exciting. It’s wonderful to present your mind with something it’s not familiar with. It’s also uncomfortable for me as a teacher. We were doing something tentative, and I was unprepared to answer questions. I’m responsible for spending time in a way that’s fruitful. If you put a lot of time into an effort that becomes hollow, that wouldn’t be a responsible use of class time…. It’s a matter of direction and leadership, groping down a path together. It requires a leap of faith, deciding that I think the path will lead someplace that will be worthwhile.
Overcoming the Obstacles

Although the obstacles to inquiry-based teaching are well documented, much less is known about effective means of helping teachers to overcome these obstacles. Our second research question addresses this gap by focusing on the ways and extent to which working collaboratively with university scientists can help teachers to implement short or long-term inquiry projects in their classrooms.

Teacher/Scientist Partnerships

Unlike most teacher professional development programs, CSIP takes place primarily in the teachers’ classrooms as teachers and fellows work together to apply new teaching strategies. In some cases, the teacher observes the fellow in action but provides little or no input in the planning and implementation stages. In more collaborative partnerships, the fellow and teacher work together throughout all stages of developing and implementing a new curriculum unit. One teacher commented:

[Fellow] and I worked very well together in the classroom. I don’t think we ever had an activity where just [fellow] led or just I led… It ended up being a dialogue between us… It’s always helpful for students to see their teachers or authority figures in dialogue, possibly disagreeing at times, you know, in kind of a positive and friendly way.

Experiencing inquiry in action in their own classrooms helps teachers to take risks that might otherwise seem insurmountable. For example, one teacher told us, “I had downloaded the bioassay curriculum, it looked interesting, and I thought about using it. But then I thought “If it didn’t work, then what?”’’ When this teacher’s classes conducted bioassay experiments under the guidance of a fellow, it turned out that the data did not agree with the class’s predictions. As the fellow led the class through analysis of their findings, the teacher learned along with the students the ways in which open-ended experiments can get students to wrestle
productively with nature of science issues such as data variability, bias, replication, and the need for experimental controls.

Inquiry by definition takes many forms, and it is implemented in many ways by CSIP fellows to meet the needs of collaborating teachers and their classes. The most ambitious partnerships last the entire school year and enable the students to engage in long term research projects. For example, in a teacher-designed high school ecology class at an alternative school, a fellow led a yearlong project in which students designed and conducted their own soil science experiments. First, he introduced the students to nutrient cycling and forest ecology and taught them seven protocols for testing soil properties such as pH, permeability, and CO$_2$ production rate. Small groups of students next developed questions related to the overall topic of the effect of worms on forest soils (a focus of his own work at Cornell), and then designed a means to investigate their questions using the protocols they had learned (Phillips & Krasny, 2001). Another fellow worked with high school biology classes to investigate the extent to which humans react to olfactory cues, producing results rigorous enough for presentation at the Annual Meeting of the Association for Chemoreception Sciences (S. Olsson, Barnard, & Turri, 2004). Another fellow is publishing a book with the National Science Teachers Association based on genetics experiments that she designed and conducted with CSIP classes.

Because long-term research is difficult to fit within the curricular constraints of most science courses, another approach taken by fellows is to refocus required labs to use inquiry strategies. For example, a CSIP fellow remodeled an Advanced Placement Biology lab in which students observe the behavior of pillbugs subjected to differing environmental conditions. This lab commonly is carried out with a straightforward list of instructions so that all students do the same experiment and get roughly the same results. The alternative approach developed by a CSIP fellow led to similar conclusions in terms of pillbug behavior.
but gave the students wide-ranging latitude in terms of designing and conducting their own experiments to investigate pillbug responses to environmental conditions (S. B. Olsson, 2004).

Another way in which fellows have built inquiry-based lessons into a single class period is through discussions that get students thinking about issues related to the nature and process of science. One fellow taught middle school students about the role of peer review in science by using a hands-on activity with fossils and a pair of articles published in the *National Geographic* having to do with the discovery of a new fossil and the subsequent discovery that the fossil was counterfeit (Gift & Krasny, 2003). Following the December 2004 tsunami, a fellow from Cornell’s hydraulics laboratory demonstrated to middle school students a computer simulation of wave travel, then discussed with them the difference between model predictions and ground truth data collected by scientists who currently were making wave height measurements along ravaged coastlines.

**CSIP Learning Community**

Although initially we focused primarily on the teacher/scientist partnerships in addressing our second research question, we have found that CSIP’s keys to success in helping teachers overcome the obstacles to inquiry lie not only in the collaborative nature of these partnerships but also in the supportive learning community in which teachers and fellows interact. In CSIP, professional development for teachers and fellows encompasses a variety of opportunities intended to develop and sustain a learning community in support of inquiry-based instruction. Components of this learning community include annual orientation sessions, periodic teacher workshops and focus group sessions, an annual student congress, and a website on which we publish curriculum resources developed by fellows or fellow/teacher teams.
**Orientation**

Each year, CSIP begins with a 2-day orientation in which teachers and fellows work together to explore ways to implement inquiry in various types of secondary level science classes. This workshop is of considerable importance in terms of developing interpersonal relationships and establishing collective norms, expectations, and conceptual frameworks. Although each school year starts with a new group of fellows, many of the teachers remain in the program for multiple years, and those with prior CSIP experience become the experts, describing to newcomers the experiences they have had working with fellows in previous years.

CSIP fellows are graduate students from a broad range of academic disciplines. Few know each other at the beginning of the school year, but a sense of community develops through their shared outreach experiences. Throughout the year, the fellows participate in a weekly seminar in which they learn about pedagogical theories, issues, and strategies, share classroom experiences, and rehearse presentations in which they introduce themselves as scientists. Some fellows develop further rapport through coteaching in the same secondary classrooms, collaborating on development of curriculum resources, or getting to know each other while commuting together to distant schools. The regularity and intensity of interaction creates a strong sense of connectedness among fellows and sense of identity with CSIP. This is less true for teachers, who are dispersed across many schools and get together through CSIP only intermittently.

**Teacher Workshops and Focus Groups**

Several times per year, CSIP teachers interact with each other and with the project team at workshops and focus group discussions. In these sessions, teachers share their
experiences working with fellows. Those new to the program get the chance to learn from
those with more experience, but even veteran teachers relish this opportunity to exchange
stories and advice. Teachers consistently comment that CSIP get-togethers have helped them
establish connections with other teachers and fellows, given them new ideas and heightened
confidence to try something new in their classrooms, and reinforced their awareness of their
own role as collaborators with an important role in the program. For example, after a session
designed for teachers to meet new fellows, one teacher realized that they were as nervous as
she was, and this experience transformed the way she perceived the fellows, her role in the
project, and the reciprocal nature of CSIP partnerships:

I've been really nervous about the program because of the brainpower of the
grad students – it's been very intimidating, but after the Thurs. program I
realize… they WANT to learn from us AND interact with our students (we're
providing them with a "lab"). The two engineers said they want to be
professors and it occurred to me as I was driving home that they will probably
start out teaching freshmen and it might appeal to them to have a chance to re-
familiarize themselves with 18 year olds before doing their post-docs!

Student Research Congress

Each year CSIP holds a student research congress that serves as a real-world context
within which participating students can share their work. The students develop posters that
present the rationale, methods, results, and interpretations of their experiments. Each student
group receives written feedback from their peers and verbal feedback from fellows, CSIP
staff, and teachers other than their own. This experience motivates students to achieve and
gives teachers an opportunity to get ideas from what has been done at other schools.

Through the orientation, teacher workshops and student research congress, the CSIP
learning community provides opportunities to make connections with others who have
common interests and goals. Teachers connect with other teachers who are interested in trying
something new, and they gain motivation and inspiration from each other. During orientation
and throughout the year, teachers also make connections with one or more fellows whose
academic background and teaching interests mesh well with their classroom needs. Often the
teacher-fellow partnerships result in a relationship characterized as more than professional.
Several teachers and fellows referred to one another as “friends” or “true colleagues” – people
with whom they hope to keep in touch beyond the end of the year. When asked about the
extent she felt connected to the fellow with whom she was working, one teacher said:

I would like to have her for my daughter. At the end [of the final field trip], I
said, “Well, I’ll see you in September, I hope,” and she said “No, we don’t get
to do this anymore.” I said, “I thought we’d grow old together!”

Although some CSIP partnerships last yearlong and others a single day, we aim for all
to be based on the principles of mutual trust and reciprocal learning. Because the fellows are
actively engaged in scientific research, they bring specialized scientific knowledge and skills
into the classroom. CSIP teachers consequently have the opportunity to learn current topics in
science and aspects of scientific inquiry from the fellows with whom they work. Fellows in
turn learn practical teaching skills as they collaborate with teachers to plan curriculum, design
age-appropriate lessons, assess student learning, and address classroom management issues.
Because of this reciprocity, fellows as well as teachers gain teaching skills while working
一起 in teacher/scientist partnerships (Trautmann & Krasny, submitted).

Fellows typically start out the year feeling worried about classroom management but
shift increasing attention to pedagogical issues as the year progresses. A fellow described the
reciprocal nature of her relationships with the two teachers with whom she had worked
intensively:

They would be a great resource for education students – helping them think
about what knowledge they needed to get out of this, what level of knowledge
they need to have (for teaching), what level of language does it need to be, and
the structure of the worksheets. (On the other hand) I was very much a
resource for the science (side of things)…
The trust that builds through reciprocal partnerships, bolstered through the support of the CSIP learning community, helps teachers overcome their ‘fear of the unknown.’ Many teachers want to try new teaching strategies but don’t feel they have the necessary support or resources to do so (Tobin & McRobbie, 1996). Through working with CSIP fellows, teachers are scaffolded in trying new approaches that they consider risky or feel unprepared to lead without assistance. As one teacher stated:

I think professionally it definitely let me try things that I probably wouldn’t have tried on my own. So, I definitely stretched myself beyond what I ever would have done individually. I think it broadened my style.

Implications

In CSIP, teams of teachers and fellows implement inquiry activities ranging from structured to open ended and from single class periods to yearlong projects. Once teachers have initiated inquiry projects, they commonly tell us about the increase in motivation, interest, and enjoyment of learning they see in their students. One teacher commented, “Students gain motivation when they do ‘real science,’ and I’ve never seen my students work as hard as when they were preparing their posters to bring to the student congress.” Another said that her students had learned “what science is about and the hard work it takes to get answers.” A teacher of a lower track science class said that participating in CSIP projects gave her students the opportunity of “finding an aspect of science that they’re interested in and can even get excited about.” A teacher of a research course for high school seniors remarked that inquiry projects are better than traditional labs because they leave a lot more room for higher order thinking. She commented that the fellow she worked with was adept at leading discussions that triggered students’ thinking about the meaning of their results. Rather than just getting the right answer, the students grappled with uncertainties about what they
had learned and how these findings fit with other topics they had studied over the course of the year.

However, student excitement about projects and enjoyment of learning do not necessarily happen right away. Students who are accustomed to learning what they need to know for the test may initially be frustrated by projects in which there is no uniquely correct answer. Teachers, too, may be wary of inquiry when their students’ projects seem to lack clear direction. One teacher described his class’s yearlong involvement with CSIP as a path that got built brick-by-brick. Together, the students, teacher, and fellow chose a project and carried it out as genuine co-researchers, with nobody being able to anticipate the outcome. The teacher stated that if they had had to quit part way through this process, he would not have recognized it as a success because of all the time that had been spent in apparent floundering as the class collectively explored options for their research project. The initial frustrations evolved into excitement on the part of the teacher and his students about the project itself and about their growing abilities to work independently in designing and conducting valid scientific experiments and interpreting their results.

Conclusion

Teachers participating in CSIP have described a complex range of barriers to incorporating open-ended inquiry in their classrooms. Not surprisingly, time constraints and the need to prepare students for high-stakes exams commonly were identified by teachers as impediments to implementing inquiry. Other barriers included concern about the possibility of not accomplishing specified learning goals and hesitancy toward breaking with traditional models of teaching. Teachers with no prior experience conducting scientific research were most likely to be intimidated by the prospect of launching into a project without predetermined answers or outcomes.
Teachers also voiced doubts about the appropriateness of inquiry for their students at both ends of the achievement scale. For example, several teachers voiced concerns about the readiness of lower achieving students to delve into inquiry and suggested that these students would need to be walked carefully through straightforward cookbook-style labs before engaging in even the most structured sorts of inquiry. On the other hand, teachers also were worried about the challenges of conducting inquiry with students who excel in traditional educational settings but become frustrated or annoyed when the expected answers are not spelled out clearly and concisely.

In our experience with CSIP teachers, we have found evidence of all four of the cultural myths identified by Tobin and McRobbie (1996) as contributors to teachers’ perception of science as a body of truths rather than a process of discovery. The transmission myth, which views the teacher as the principal source of knowledge to be delivered to students, is seen in teachers’ discomfort with not knowing the answers to students’ questions or the expected outcomes of their open-ended experiments. The needs for efficiency, maintaining the rigor of the curriculum, and preparing students to succeed on examinations together explain the reluctance of many teachers to divert from traditional models of teaching to try implementing the potentially more risky approach of inquiry-based learning. As Tobin and McRobbie (1996) point out, collectively these myths translate into content coverage being considered more important than learning with understanding because in-depth understanding is not necessarily required for success on high-stakes exams.

In spite of the power of these obstacles to inquiry, we have found that many teachers are interested in implementing open-ended inquiry in their classrooms. NSF’s GK-12 program provides the opportunity for teachers to collaborate in long-term partnerships with science graduate students and participate in a learning community comprising fellow teachers and university scientists and educators. The scaffolding provided through these partnerships and
associated learning community enables teachers to take increased risks in their classrooms. When fellows and teachers collaborate to facilitate student inquiry projects, together they deal with unexpected or unknown outcomes, address misconceptions, and determine how open-ended inquiry-based learning can best be used in specific classroom settings. This helps teachers overcome their initial hesitation and see the benefits that inquiry learning can produce in terms of motivation and achievement of students at a variety of grades and achievement levels.

Because participation in CSIP is voluntary, we cannot claim that similar benefits would be felt by teachers who are not as motivated to try inquiry-based teaching. However, for teachers interested in making the leap to open-ended student inquiry, collaboration with science graduate students appears to be an effective means of overcoming initial hurdles and gaining confidence in the value of this less teacher-driven approach to student learning.

**Literature Cited**


POSITIVE AND LESS THAN POSITIVE ASPECTS OF AN ON-LINE SCIENCE EDUCATION PROGRAM

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Linda James, East Carolina University

Abstract

There has been a trend in recent years toward developing graduate programs in education (including science education) that are largely or totally available on-line, though distance education. Although most of these programs are relatively new, there has been some opportunity for appraisal of effectiveness as compared to traditional, face to face programs. This paper will include discussion of the distance delivery graduate programs at East Carolina University in Greenville, North Carolina. A brief history of the reasons for movement toward distance instruction will be included, along with a description of the process of designing and developing the programs.

Introduction

The delivery of education through distance formats can be traced back to at least 1840, when Isaac Pitman taught shorthand by the means of correspondence, eventually leading to the establishment of the External Programme by the University of London in 1858 (Moore, 1996). In 1890, James Foster began a home-study course in mining from the Colliery Engineer School of Mines in Pennsylvania, and Pennsylvania State College initiated an agricultural studies correspondence course in 1892. The Ford Foundation initiated grants to institutions for the development of educational programs in 1950, and in 1967 the Corporation of Public Broadcasting was created. In 1968, Stanford University created the Stanford Instructional Television Network, and brought about a new learning environment for students.

In the 1960’s, classes involving as many as 300,000 students were taught utilizing radio and television delivery, and by the 1980’s computers were being used to deliver instruction (Gooch, 1998). By 1992 use of computers began to dominate distance education. George Washington University started a master’s program Educational Technology Leadership using a computer bulletin board system. Duke University began a Global Executive M.B.A. Program which served individuals not only in the United States but also in
Europe, Asia, and Latin America. John Hopkins University followed in 1997 by starting a Medical Certificate Program over the internet. By 1999, leaning tools such as, HungryMinds, Learn2, and Blackboard introduced new tools for delivery of instruction (Arenson, 1998). Electronic tools such as Blackboard help provide the learned with a more familiar, uniform learning environment (Huges, 1994).

Online distance education programs should begin with the development phase and understanding of the key roles of all individuals involved in the process. The actual process can be divided into three stages of design and development (Ehrmann, 1995). The design of the program should start with a clear concept of eventual goals, along with research of the curriculum that is necessary to effectively provide instruction. The second step is to design lesson plans according to time constraints and curriculum. The third and final step of the design process is to provide a prototype of the class and to analyze the results. The design process of a distant education program should be gauged by whether its curriculum could be understood and completed by a mass audience (Dick, 1990).

Purpose

The purpose of this paper is to provide information about the development of online distance education programs for those who may be planning or beginning their own programs. The authors were directly responsible for the planning and establishment of the on-line science education program at East Carolina University. That program is now up and running, with approximately 20 students enrolled. The paper will also provide information about the reasons for establishing such a program, along with positive and negative impacts of online distance education programs.

Before beginning, it should be noted that at least one of the authors of this paper had serious misgivings about the changeover to a distance delivery format for the master’s program in science education at East Carolina University. The on-campus program had
operated successfully for many years, although the number of students enrolled had gradually declined. Just a few years earlier (1998-1999), the program had been modified to meet new state “advanced competency” standards, and to encourage enrollment of elementary and middle-grades teachers. Although the program was somewhat less rigorous in terms of science content than earlier programs, it allowed the science education faculty to fully control scheduling of classes. In some ways, this restructuring allowed for easily adaptation of the program to distance delivery. This is because it is possible for science educators to teach all of the science education and science courses in the program (although students are encouraged to take up to 9 semester hours in the straight science areas). The related education courses are taught by faculty in the various education departments, and all are available online.

Although the distance education online program in science education is essentially the same as the previous on-campus program, it had to be approved by six campus committees and one state level committee. This was an extremely time-consuming process, and again, it was undertaken with some reluctance. The reason for the reluctance was that the change was being made for almost purely financial reasons. Due to changes in leadership directions at East Carolina, the science education program had been shuffled through a succession of three departments within a three year period. Enrollment and financial concerns became much more of a priority than quality of programs. Online distance education was seen as a way to increase income for the whole university, so an emphasis was placed on development in this area. Faculty incentives included increased pay for overload courses and increased travel funding. Equipment budgets for anything related to distance education were also greatly expanded. All of these factors helped influence the development of an on-line program in science education.
Following are several documents related to the development to the on-line program in science education at East Carolina University. The program is now in its first year of operation. Due to financial constraints, the on-campus version of the program is no longer in operation.

Description: MAEd in Science Education (Pre-1999)

The MAEd in Science Education is designed to improve the knowledge and skills of the classroom science teacher. This program is open to those students who hold undergraduate degrees in education and to students who hold undergraduate degrees in a science content area.

Course Requirements: A minimum of 36 s.h. is required with at least 18 s.h. at the 6000 level or above. The specific program of courses must meet the requirements below and be approved by the student's adviser.

1. A minimum of 18 semester hours of science education courses, including specified core courses.
2. Six semester hours of professional education courses, taken under advisement.
3. The remaining 12 semester hours of coursework shall be selected from the fields of biological, physical, and earth science. Appropriate prefixes include: BIOL, CHEM, GEOL, PHYS, and SCIE.

All students will complete a research problem or thesis. If the thesis option is selected, it may be satisfied through satisfactory completion of SCIE 6995 and 6996. If a research problem is selected, it may be satisfied through satisfactory completion of SCIE 6505, 6506, or 6507. A comprehensive examination in Science Education must be passed at the completion of the program.

Description: Master of Arts in Education (MAEd) Teaching Field: Science Education (Present)

The MAEd with a Teaching Field Option of Science Education is designed to improve the knowledge and skills of the classroom science teacher.

Course Requirements: A minimum of 36 s.h. is required with at least 18 s.h. at the 6000 level or above. The specific program of courses must meet the requirements below and be approved by the student's adviser.

1. Twelve semester hours of professional education courses which make up the MAEd core, including EDUC 6001; SPED 6002; SCIE 6500; and LEED 6000 or ADED/ELEM 6550.
2. Twelve semester hours of science education courses, including: SCIE 6020, 6200, 6310, and 6600.
3. Three semester hours of thesis or problems credits. All students will complete a research problem or thesis. Students choosing the research problem option must complete SCIE 6505 OR 6506 OR 6507. Students choosing the thesis option must complete SCIE 7000.
4. Nine semester hours of coursework shall be selected from the fields of biological, physical, and earth science. A comprehensive examination in Science Education must be passed or a professional portfolio must be completed at the culmination of the program.

Changes Reflected in the New Program

The most significant change in the new program (as compared to the program shown in the present catalog) is that it has been re-designed to cater to the needs of active teachers in the schools. The new MAEd includes fewer courses that emphasize philosophy and theory, and more courses that will help teachers become more effective in their own classrooms. There has also been a shift from courses that emphasizes traditional or basic research, to courses that emphasize applied or action research. The old program was open to students with an undergraduate degree in education or an undergraduate degree in a science content area. The new program is open only to licensed teachers. Again, this will allow faculty to focus on the needs of practicing teachers as opposed to a more diverse student base.

Specific changes are shown below:

<table>
<thead>
<tr>
<th>Old Program</th>
<th>New Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 s.h. SCIE courses:</td>
<td>12 s.h. SCIE courses:</td>
</tr>
<tr>
<td>SCIE 6010 History and Philosophy</td>
<td>SCIE 6020 Recent Developments</td>
</tr>
<tr>
<td>SCIE 6020 Recent Developments</td>
<td>SCIE 6200 Environmental Education</td>
</tr>
<tr>
<td>SCIE 6500 Research</td>
<td>SCIE 6310 Advanced Methods</td>
</tr>
<tr>
<td>SCIE 6501 Experimental Evaluation</td>
<td>SCIE 6600 Action Research</td>
</tr>
<tr>
<td>6 s.h. Professional Education</td>
<td>12 s.h. Professional Education (core)</td>
</tr>
<tr>
<td>(Unspecified) Students would often take:</td>
<td>SCIE 6500 Research</td>
</tr>
<tr>
<td>EDUC 6423 History and Philosophy</td>
<td>EDUC 6001 Intro. to Differences in Learning</td>
</tr>
<tr>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td>EDUC 6424 Foundations &amp; Curriculum</td>
<td>LEED 6000 Leadership and Communication</td>
</tr>
<tr>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td>EDUC 6454 Foundations of Education</td>
<td>ADED/ELEM 6550 Leadership/Communication</td>
</tr>
<tr>
<td>12 s.h. Pure Science</td>
<td>9 s.h. Pure Science</td>
</tr>
<tr>
<td>BIOL, CHEM, GEOL, PHYS Research</td>
<td>BIOL, CHEM, GEOL, PHYS Research</td>
</tr>
<tr>
<td>Thesis or Problems Course Required</td>
<td>Thesis or Problems Course Required</td>
</tr>
<tr>
<td>Comprehensive Exam Required</td>
<td>Comprehensive Exam or Professional Portfolio</td>
</tr>
<tr>
<td>Total 36 s.h.</td>
<td>Total 36 s.h.</td>
</tr>
</tbody>
</table>

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Development of an on-line MAEd science education program at East Carolina University (Planning Document)

The following procedures will guide development of online courses for the SCIE master’s degree program. Faculty plan to complete online core-course development by Fall Semester, 2004.

Identify a timeline for offering online versions of existing campus-based core courses in SCIE (6010, 6019, 6020, 6310, 6500, 6600).

Develop and run a pilot version of each online version of campus-based SCIE core courses, using an appropriate format (ECU-Blackboard or web based)

Develop and distribute an electronic brochure to be sent to NC public schools, by August 1, 2003.

Offer the online version of the SCIE master’s degree program Fall Semester, 2003.

The following assumptions underlie the development of an online program of advanced study leading to the master’s degree in science education. The Master’s degree programs in science education (MA/MAEd) will provide practicing science teachers an opportunity for advanced, professional growth.

The graduate program offers science teachers an opportunity to acquire advanced knowledge and understanding of science, science teaching/learning, and science teacher research.

Graduate courses blend advanced academic study with reflective practice in the context of science teachers’ current teaching assignments.

A Master’s degree program in science education offered online would greatly extend the pool of potential applicants for graduate study beyond eastern North Carolina.

Required “core” courses in science education would be offered on a rotational basis each year, in keeping with the needs of graduate students enrolled in the program and the availability of faculty.

Courses in SCIE included in the Master’s degree program would reflect the teaching/research interests, strengths, and expertise of program faculty.

Tentative Schedule (for planning)

The following is the plan proposed for developing and offering core courses in the online version of the SCIE master’s degree program. The last column indicates when the online version of the courses was offered. The final table includes a projected schedule of course offerings.

<table>
<thead>
<tr>
<th>SCIE Courses</th>
<th>Online Status</th>
<th>Offered online</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCIE 5010</td>
<td>Developed- Fall 2002</td>
<td>Fall 2002</td>
</tr>
</tbody>
</table>
Sample Sequence of Courses
On-line MAEd Program
Science Education
Fall, 2003
  SCIE 5010 Teaching Science Using Microcomputers
  Spring, 2004
  SCIE 6500 Understanding and Engaging in Educational Research
  Summer I, 2004
  SCIE 6020 Recent Developments in Science Teaching
  Summer II, 2004
  SCIE 6310 Advanced Methods in Science Teaching
  Fall, 2004
  SCIE 6200 Environmental Education
  Spring, 2005
  SCIE 6600 Action Research in Teaching
  Summer I, 2005
  SCIE 6003 Selected Topics in Life Science
  Summer II, 2005
  SCIE 6004 Selected Topics in Physical Science
  Fall, 2005
  SCIE 6505, 6506, 6507 or 7000 Problems in Science Teaching
  Spring, 2006
  EDUC 6001 Foundations
  Summer I, 2006
  SPED 6002 Diversity
  Summer II, 2006
  ELEM/ADED 6550 Leadership and Communication

Note: Students can accelerate completion of their program by completing EDUC 6001, SPED 6002, ELEM/ADED 6550, and/or SCIE 6505, 6506, 6507 earlier than scheduled.

Positive and Negative Aspects of the Science Education On-line Graduate Program

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Positive

Convenience for graduate students, particularly those in isolated areas.

Increased enrollment, along with increased funding possibilities.

Increased production of science teachers, particularly if ties can be made with licensure programs.

Intense action research in science classrooms, since most of the enrolled teachers are active in their own classrooms.

Increased research, publication, and presentation opportunities (partially due to the increased enrollment).

Negative

No face to face interaction with students.

Technology problems (student, instructor, and university).

Problems with sharing of information, including presentations with the instructor and other students.

Lack of opportunities for faculty to closely mentor outstanding students, including production of theses.

For some faculty, distance education does not provide the opportunities for “real” teaching (direct, face to face instruction).

Program Assessment

The MAEd program is still too early in its development to make any serious statements about the success or failure of the on-line program as compared to earlier versions. The change-over has been gradual, since students have been taking some of their required courses through distance education for approximately three years. There has been some impact on faculty, mainly in terms of teaching load (which seems heavier with the new on-line courses), but also in terms of teaching satisfaction. Some of the faculty involved seem quite satisfied with teaching on-line courses, and may even be more effective teaching through this format than through traditional means. Other faculty are not at all satisfied teaching through a distance education format, and do not feel that they are really teaching at all.

It seems clear that development of online distance-based programs is the way of the future in higher education. It is possible that programs and courses will be refined to produce
a truly quality product. The part of this trend that is somewhat depressing is that it is all based on economics and competition for new students. The trend seems to have little to do with quality or with increases in meaningful learning among the students.

Although the catalyst for the development of the online distance education program was enrollment numbers and financial feasibility, the professors who are now the primary instructors at ECU (Crawley and James) are enthusiastic about the quality of the projects that the graduate students are producing. These two key instructors are in the process of evaluating the online courses and aligning products in the methods courses so that extended research action projects can be continued in the action research or recent issues courses. They are also utilizing more technology, such as digital photographs, and video and audio clips, into the required products. The program is also in the process of being aligned to National Board Certification Teachers and National Science Teachers Association teaching and professional development standards.

References


