EVERYDAY PHYSICS:
LISTENING TO PRE-SERVICE TEACHERS REFLECT ON LEARNING AND
TEACHING SCIENCE THROUGH INQUIRY

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ABSTRACT

Inquiry-based learning is believed to be one of the most effective ways to teach and learn science. However, many teachers are hesitant to use the method in class. The University of Akron recently began offering a one semester inquiry-based physics course to education majors. The course, Everyday Physics, is taught using inquiry-based instruction with embedded lecture. One of the main goals of the course was to help students become confident in their ability to practice and teach authentic science. The purpose of this project is to investigate the course’s successes and difficulties with implementing inquiry-based instruction and increasing students’ science teaching and learning self-efficacy. The project considers data gathered during the Spring semester of 2006. Participants include 21 middle-level education majors. Sources of reflection include journals in which students made entries throughout the semester and classroom observation. Our data indicate that most of the students in Everyday Physics were able to increase their self-efficacy for both learning and teaching inquiry-based science.
ACKNOWLEDGEMENTS

The Students of Everyday Physics, Spring 2006

Rex Ramsier
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CHAPTER I

BACKGROUND

Educational theorists have been promoting the use of inquiry-based science instruction in literature for almost 100 years, yet it is rarely seen being practiced in schools today (Supovitz et al., 2000; Palincsar, 1998). Despite what seems like a failure of implementation, inquiry is still believed to be one of the most effective teaching methods (Supovitz et al., 2000; Kruckeberg, 2006; McBride et al., 2004; Drayton & Falk, 2001; Pressley & Woloshyn, 1995). The National Science Education Standards state that: “Inquiry into authentic questions generated from student experiences is the central strategy for teaching science” (NRC, 1996, chapter 3), and recommends the inquiry-based teaching of science. There is abundant research showing that meaningful learning takes place when students actively construct their own learning experiences through inquiry (Brass et al., 2003). Why, then, do so few teachers use inquiry methods in the classroom?

There are many reasons (McBride et al.; 2004, Supovitz et al., 2000; Drayton & Falk, 2001). The inquiry movements of the 1920’s and 1950’s are thought to have failed because they did not have enough impact on practicing teachers (Supovitz et al., 2000;
Palincsar, 1998). Putting theory into practice is difficult (Mueller & Skamp, 2003) and teachers need support and training to be able to effectively make changes in practice (Bitan-Friedlander et al., 2004; Palincsar, 1998). Since teachers did not have this support in the past, inquiry did not become widely used. The current reform is therefore focusing on practicing teachers’ professional development (Supovitz et al., 2000). Teachers are accustomed to teaching science as a body of knowledge, and students are accustomed to learning it this way (McBride et al., 2004). It is also much more daunting and time consuming to both construct and conduct a lesson plan that involves active student inquiry than a direct instruction lecture (Drayton & Falk, 2001; McBride et al., 2004).

Today’s teachers are concerned with meeting standards and covering all the topics addressed by standardized tests (McBride et al., 2004). Inquiry teaching focuses on depth of knowledge, rather than a wide, but shallow, breadth of factual knowledge. Teachers worry that they will not be able to cover enough information in a limited amount of time. It is also more difficult to evaluate when students are constructively learning (Hammer, 1995; McBride et al., 2004). Teachers may be uncomfortable if they think that the students are going in the wrong direction in a discussion (Hammer, 1995). They believe that inquiry-based teaching requires them to steer the discussion back on track without discouraging participation or simply giving away the correct answer, which can be a challenge. Teachers worry that letting the students discuss and explore on their own may lead to confusion or incorrect conclusions (Hammer, 1995). Despite all these potential challenges, with support and adequate training, teachers can learn to facilitate student inquiry in a successful way (Drayton & Falk, 2001; Supovitz et al., 2000). Inquiry-based
teaching does not have to be daunting or overwhelming, and the benefits to the students who construct their own knowledge and learning experience is immense.

In the Spring of 2004, Dr. Rex D. Ramsier developed a new course that was offered exclusively for education majors through the Physics Department at The University of Akron. The course, “Everyday Physics” has been offered and run during the Spring semesters of 2004, 2005, 2006, and 2007. The course is taught using the inquiry-based method with embedded lecture, as we wished to introduce the pre-service teachers to the inquiry method in action while at the same time teaching content knowledge. According to Supovitz et al. (2000), pre-service teachers must learn by inquiry in order to be able to effectively teach using inquiry. Thus, the instructor serves as a model for inquiry-based instruction while using a variety of inquiry activities to facilitate student discovery and experiential learning. Most of the activities performed in Everyday Physics use everyday materials and inexpensive equipment that teachers have easy access to and can afford. This course is a unique opportunity for pre-service teachers to link pedagogy to area content knowledge. By modeling the inquiry method to students, we hope to not only teach physics content knowledge, but also a method of teaching and learning science that will be useful to them in their future classrooms.

During the Spring semesters of 2006 and 2007, the present author was a Teaching Assistant for “Everyday Physics”. As a Teaching Assistant, I was actively involved in the teaching and planning of the course, and served as a knowledgeable peer to the students. The class was geared toward education students who planned on teaching middle-level science. The students were not expected to have any science background, and many were uncomfortable with the idea of learning and teaching science. One of our main goals was
to help these students become comfortable and confident in their ability to practice and teach authentic science.

The purpose of this Master’s project is to investigate the course’s success of implementing inquiry-based teaching, the changes in students’ self-efficacy for teaching and learning inquiry-based science, the predicted impact on their future practice, and on the lessons learned from the experience. Sources of investigation include journals in which students made entries throughout the semester and classroom observations.
1. Constructivism: The Cognitive Basis of Inquiry Learning

Constructivism is the theory that meaningful learning takes place when learners actively construct their own knowledge (Brass et al., 2003, Kruckeberg, 2006; Arends, 1997; Zion & Slezak, 2005; Cobern, 1993; Watson, 2001; Palincsar, 1998). According to Cobern (1993), “Knowledge is a meaningful interpretation of our experiences of reality.” People learn by constructing an understanding of their experiences in relation to what they already know. Everyone learns differently because everyone has different prior knowledge of the world, and a different way of interpreting experiences. According to constructivism, it is actually impossible to learn by direct transmission, since the knowledge being learned cannot be separated from the learner (Cobern, 1993; Watson, 2001; Palincsar, 1998).

This theory of learning explains a common problem in science education. Many science students have ideas and beliefs about scientific concepts such as acceleration or evolution that are significantly different than the scientifically accepted theories (Cobern,
1998; White, 1993; Norvilitis et al., 2002). Even when the students are taught the accepted theories, they maintain their misconceptions. This is easily understood when we consider that the students constructed their beliefs based on their interpretation of reality, built on their prior experience, knowledge, and understanding. Unless the learner is able to make sense of this new knowledge with respect to their prior knowledge, it will not be internalized (Cobern, 1998; Bruning et al., 2004). Therefore, a learner must take an active role in interpreting and internalizing knowledge to make meaningful learning possible (Arends, 1997; Kruckeberg, 2006; Cobern, 1993; Watson, 2001; Palincsar, 1998). This is the main tenet of constructivism.

Two main branches of constructivism are individual and social constructivism (Cobern, 1993; Palincsar, 1998). Piaget (1965) and Vygotsky (1997) are two well-known proponents of the constructivist theory of learning. Piaget was an individual constructivist who believed that a child’s learning depended on their internal development, and that children cannot learn certain things until they reach a certain developmental stage. According to Piaget’s theories, learning should follow a child centered model. On the other hand, Vygotsky was a social, or dialectical, constructivist. Vygotsky focused on the social context of learning, and believed that children learn through interactions with adults or more knowledgeable peers. Vygotsky’s (1997) research indicates that children are not limited in what they can learn by stages of development. According to Vygotsky, learning should be a reciprocal process; it should focus neither on the child nor the teacher, but on the interaction between them. Piaget focused on the internal thought processes of a learner, while Vygotsky focused on the greater social and cultural context of learning.
According to Vygotsky, social interaction is at the root of construction of new knowledge (Arends, 1997; Cobern, 1993; Palinscar, 1998). With the assistance of teachers, students can go beyond their current level of development to discover new ideas (Arends, 1997). Vygotsky believed that learning takes place in the zone of proximal development. This is the area of development between a learner’s actual development and the level of possible development with the guidance of a teacher or more knowledgeable peer (Bruning et al., 2004; Arends, 1997). Through this social interaction, learning takes place and is internalized by the student. Teachers guide learners through the zone of proximal development with instructional scaffolding. Scaffolding is a way for teachers to help learners do something they would be incapable of doing on their own, without simply telling them the answer (Bruning et al., 2004). Instead, they guide the student to discover the answer themselves.

Inquiry-based learning is a logical outcome of social constructivism. According to social constructivism, learning takes place when students and teachers work together to co-construct knowledge through investigation, asking questions, and seeking answers (Kruckeberg, 2006; Arends, 1997; Watson, 2001; Bruning et al., 2004). Effective learners are open to challenging their own conceptions based on appropriate evidence and arguments (Kruckeberg, 2006). These are the learning goals of an inquiry-based classroom; where students investigate questions and challenge preconceptions with the guidance of a teacher, and are active learners, not passive (Kruckeberg, 2006; Arends, 1997; Watson, 2001; Palinscar, 1998; Brass et al., 2003).
2. Inquiry-based Instruction versus Traditional Instruction

Students are traditionally taught to see physics as an authoritative body of factual information and equations, unchanging and unrelated to personal experience (Smith & Anderson, 1999; McBride et al., 2004; Pressley & Woloshyn, 1995). Most classrooms are teacher centered and usually consist of a direct instruction lecture with the teacher lecturing and solving example problems at the board (Garvin & Ramsier, 2003). Teacher centered classrooms focus on facts, rather than the thought process (Drayton & Falk, 2001). Many teachers are comfortable teaching physics this way, and many students are used to learning it this way (McBride et al., 2004). Nearly all science teachers rely on texts for curriculum and instruction, and most texts encourage only superficial learning, such as memorization (Pressley & Woloshyn, 1995). Texts rarely facilitate higher order thinking, since they mostly represent science as a collection of static facts (McBride et al., 2004).

Teachers often focus on teaching students to solve quantitative problems (White, 1993), and although teachers often present students with problems which require higher order thinking to solve, they also demonstrate the solution (Pressley & Woloshyn, 1995). The result is that students memorize an algorithm for solving these problems without truly understanding what they are doing (Pressley & Woloshyn, 1995; White, 1993). Students will memorize equations and learn to solve word problems by putting the variables given into equations to try to arrive at the desired answer. The students successfully learn to solve algebraic equations, but cannot make the connection to the real world and often cannot explain what they are doing conceptually (White, 1993). This
method of problem solving, although often enabling a student to pass a course, does not represent how scientists solve problems in the field.

Students may be very academically successful at learning physics as a body of knowledge (Garvin & Ramsier, 2003), and have no desire for a change in instruction style. Other students, however, have considerable trouble with this style of teaching and learning. They find it difficult to relate scientific facts to their personal experience and feel uncertain and insecure in their ability to understand science (Smith & Anderson, 1999). Many students will say they are “just not good at science” and thus take as few science classes as possible.

There is a drawback to traditional instruction for the academically successful students as well. Students’ learning is often shallow and short lived (Brass et al., 2003). Students may have misconceptions about everyday physics, even when they have taken a course in physics (Norvilitis et al., 2002). For example, many students who took and passed high school physics and even college physics answer incorrectly when asked to describe the path of a ball rolled off a table or kicked off a cliff (White, 1993; Norvilitis et al., 2002). Students have internalized beliefs about how the world works when they come into a physics class (Norvilitis et al., 2002). These beliefs often clash with scientific viewpoints (Pressley & Woloshyn, 1995).

If students do not address their established beliefs, they can not accommodate or assimilate new knowledge into existing schemes. The result is that students will encounter a personal dichotomy. They will truly ‘believe’ one reality, but will retain another for academic purposes, i.e. test taking (Brass et al., 2003; White, 1993). If the class does not challenge their internalized beliefs, students will leave class with the same
concepts they came in with, even if they performed well on traditional assessment instruments (Kruckeberg, 2006). Didactic instruction typically ignores the fact that most students have incorrect prior knowledge, and this leads to problems in student learning (Kruckeberg, 2006). One way to challenge students’ internal beliefs is to allow them to test their theories through experiment (Norvilitis et al., 2002). When students are forced to confront their misconceptions through experimentation, they can no longer be equivocal and must reconcile the differences. Students are more likely to believe and internalize the scientific viewpoint if they can discover it themselves. This is one of the goals of inquiry-based instruction.

Inquiry-based instruction (also referred to as guided discovery, problem-based instruction, and experiential learning) is different than traditional instruction in that it teaches science as a process of learning how the world works (Drayton & Falk, 2001; Smith & Anderson, 1999). It takes into account the ever-expanding body and the wide range of scientific knowledge and teaches students the role of evidence, the scientific method, and the greater scientific community (Drayton & Falk, 2001). The inquiry-based classroom is much different from the didactic classroom in that it is student centered. Students are expected to take responsibility for their own learning and are active rather than passive (Zion & Slezak, 2005). Unlike direct instruction, inquiry-based instruction can develop students’ problem-solving skills and engage students in higher order thinking and metacognition (Arends, 1997).

There are numerous studies suggesting that inquiry effectively increases student achievement and skills, and fosters a positive attitude toward science (Supovitz et al., 2000; Pressley & Woloshyn, 1995; Palinesar, 1998). Through inquiry-based teaching,
students learn how to use the same methods and processes that scientists use to conduct problem-based investigations (McBride et al., 2004). According to the theory of experiential learning, learning through experience provides understanding that is deeper than other learning methods. Inquiry-based instruction provides a method for teachers to facilitate student experience in discovery. Inquiry-based instruction increases students’ content knowledge while at the same time encouraging innovation and discovery (Arends, 1997).

There are some drawbacks to inquiry-based instruction (Brown et al., 2006). No one single method of instruction can meet the needs of all students (Smith & Anderson, 1999). Some students may need more structure than that provided by inquiry instruction. Inquiry instruction is also not an effective way to disseminate a large quantity of information to many students in a short period of time. Teachers also do not have as much control over the content of student learning, since the classroom is student-centered. Many teachers perceive inquiry to have drawbacks, such as taking too long, being ineffective, and being too difficult to implement (Brown et al., 2006). Whether or not these beliefs are supported, they themselves are a drawback to inquiry which limits its use.

One of inquiry’s benefits can also be seen as a drawback: When students become engaged in an activity or discussion, the instructor may wish to let the students continue to investigate. Because of time constraints, this is not always possible. Some of these drawbacks can be overcome with more exposure to inquiry learning. Some of the drawbacks are a natural consequence of the inquiry instructional methods. It is the
present author’s opinion that benefits of inquiry-based instruction are far greater than the
drawbacks.

According to McBride et al. (2004), teaching the process of science as inquiry is
more important than teaching factual knowledge. Learning the process of inquiry is
procedural knowledge, while learning facts is declarative knowledge (Bitan-Friedlander
et al., 2004). As Kruckeberg (2006) explains, declarative knowledge is learned through
the use of procedural knowledge. Therefore, teachers should focus on teaching students
the methods of inquiry through procedural knowledge (Kruckeberg, 2006). In other
words, if students are taught how to do science, they will be able to find factual
information easily on their own. Although learning science through inquiry involves
learning less factual information, students gain a greater depth of understanding
(McBride et al., 2004).

According to Arends (1997), a teacher’s role in inquiry-based instruction is to
present problems or questions for students to investigate and provide scaffolding for
student discovery. Teachers should not give students specific directions for solving the
problem or talk “at” the students (Drayton & Falk, 2001). Instead, they should provide
guidance, ask leading questions, and support the students in their discovery (Zion &
Slezak, 2005; Drayton & Falk, 2001). The NRC’s guidelines for inquiry instruction state
that “At all stages of inquiry, the teacher guides, focuses, challenges, and encourages
student learning” (NRC, 2000). It is essential that the inquiry classroom is open to all
student ideas and questions (Arends, 1997). If students are immediately corrected by the
instructor whenever they voice an incorrect idea or theory, they will soon cease to offer
any theories or ideas at all (Hammer, 1995). According to social constructivist theory,
the essence of inquiry learning is in the interaction between student and teacher (Zion & Slezak, 2005). Therefore, teachers should strive to create an intellectually safe learning community in the classroom (Zion & Slezak, 2005).

According to Arends (1997), there are five instructional phases of an inquiry-based lesson. In the first phase, teachers orient the students to the problem being investigated. Teachers should present their students with real-life problems that are complex and do not have one simple answer (Arends, 1997; White, 1993). During this phase, the teacher should explain what is expected of the students in terms of evidence and social interaction with peers (Drayton & Falk, 2001). When students understand why they doing something and what is expected of them, they will put forth more effort and are more likely to learn (Arends, 1997; Drayton & Falk, 2001).

In the second phase, the teachers organize students for study. This is the phase in which desks are arranged for group work and students are assigned to groups, if necessary. This phase may also take place before problem orientation. The third phase is when students engage in investigation and discovery. During this phase, teachers should scaffold students and provide guidance, but should not tell the students what to do or if they are right or wrong (Arends, 1997; Zion & Slezak, 2005). The goal of the teacher should be to facilitate student investigation and discovery, not provide answers. During the fourth stage, students should discuss what each group found and how they investigated the problem. The fifth stage engages students in reflection on the inquiry process.
Although inquiry-based classrooms do not have to be group based, or cooperative, the present author believes this is the most effective classroom arrangement. In the next section, we will discuss the benefits of cooperative learning.

3. Cooperative Learning

Classrooms generally have one of three types of goal structures: competitive, individualistic, and cooperative. A competitive goal structure is one in which individuals are rewarded in relation to others, such as a curved grading scale (Arends, 1997). Only a limited number of students can succeed, and students are forced to work against each other (Johnson et al., 2002; Ramsier, 2001). Students are encouraged to deprive classmates of success, and end up celebrating the failures of peers (Johnson et al., 2002; Arends, 1997). In a competitive structure, students do not help each other for fear that to do so would lower their own grade (Ramsier, 2001; Johnson et al., 2002). Individualistic goal structures reward students individually, without comparison to peers (Arends, 1997). Although individualistic structures do not punish students for helping peers, they are not encouraged or rewarded for doing so (Johnson et al., 2002; Arends, 1997). In a cooperative goal structure, students are forced to work together. Each student’s success is contingent on the success of their peers (Arends, 1997). Students are rewarded based on the success of the group, not on the success of the individual. Therefore, students want to help each other, and celebrate the successes of their peers (Johnson et al., 2002). As opposed to competitive or individualistic structures, cooperative structures encourage
caring and supportive relationships and increase student confidence (Johnson et al., 2002).

Although all three goal structures are useful for various types of instruction, cooperative learning best promotes a classroom environment conducive to inquiry-based instruction. In the cooperative classroom, students work in small groups or pairs toward a common learning goal (Johnson et al., 2002). Since students must engage in both team work and task work, cooperative learning is more complex than other instructional methods (Johnson et al., 2002). However, the benefits of cooperative learning are great. For example, being able to function well in a team is one predictable benefit of cooperative learning (Ramsier, 2001; Arends 1997; Pressley & Woloshyn, 1995).

Students are rarely rewarded on the basis of the success of their group, and it can take time for students to adjust to this method. With practice, cooperative learning improves students’ social behaviors and promotes relationship-building skills in ways that other methods cannot (Johnson et al., 2002; Arends, 1997; Pressley & Woloshyn, 1995). Another, less predictable outcome of cooperative learning is improvement in academic achievement. Cooperative efforts promote increased student productivity as well as higher academic achievement (Arends, 1997; Johnson et al., 2002; Pressley & Woloshyn, 1995). Critical thinking skills are also improved, and students are more likely to understand everyday science in a cooperative environment (Norvilitis et al., 2002; Arends, 1997).
4. The Role of Reflective Practice

What is the role of reflective practice in the learning process? To answer this conceptual question, reflective practice must be defined. Reflection is widely viewed as an essential part of teacher education (Jay & Johnson, 2002; Mueller & Skamp, 2003). Although many teacher education programs incorporate reflection in the curriculum, there is not a single, clear definition of reflective practice (Jay & Johnson, 2002, Hatton & Smith, 1995). Educational research can focus on topics ranging from the content of reflection to the pedagogy of reflection. In practice, students may be encouraged to reflect only on content knowledge (what they have learned), or they may be encouraged to reflect on the process of learning (how they learned).

According to Brass et al. (2003), metacognition is a crucial part of learning. Metacognition can refer to knowledge of cognition in general, or it can refer to the process of monitoring and regulating one’s own cognition; i.e., metacognitive control (Pintrich, 2002). Metacognitive control is a cognitive process used to monitor and regulate learning and thinking, and is used in activities such as reflection (Pintrich, 2002). Through reflection, students become aware of their own cognition and learning processes (Pintrich, 2002, Mueller & Scamp, 2003). In Everyday Physics, students wrote in daily reflective journals. They were given journaling prompts that encouraged them to focus and reflect on the process of how they were learning (See Appendix D).

Journaling was an essential part of the class for many reasons. It can help students work through and learn from failure (Ramsier, 2001), and help them be better able to deal with problems which require knowledge and skills that they do not yet
possess (Pintrich, 2002). These are valuable qualities to instill in students, especially in an inquiry-based classroom. Also, journaling teaches students to regulate their own behaviors and cognitive processes, which is necessary in order for them to be successful learners (Bruning et al., 2004). Besides the benefits to students, journaling is valuable to the instructors. Teachers can gain valuable knowledge about student learning from journals, and incorporate interventions into their teaching (Mueller & Skamp, 2003).

According to research, reflection on practice is also an integral part of the best teaching practices (Hatton & Smith, 1995). By incorporating daily reflection into this course, students’ gained insight into their current learning processes, and they also gained experience with a valuable tool to use in their future classrooms.

5. Self-Efficacy

Self-efficacy is the belief in one’s ability to perform certain tasks or reach certain goals, and is situation specific. In this thesis, self-efficacy and confidence will be referred to interchangeably. Most individuals will choose to perform tasks for which they have high self-efficacy, and avoid tasks for which they have low self-efficacy (Bruning et al., 2004). Students with higher scholastic self confidence are more likely to attempt difficult tasks (Norvilitis et al., 2002). Students with high self-efficacy are also more likely to be persistent and exert more effort to achieve a goal (especially when faced with difficulties) than those with low self-efficacy (Bruning et al., 2004). Because of this, students with high self-efficacy are more likely to learn and achieve.
According to Bandura, there are four sources of self-efficacy: enactive mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states (Bandura, 1997). An enactive mastery experience (sometimes referred to as task accomplishment) is a successful experience or performance of the task or activity. The knowledge that one has previously been successful in accomplishing a task is a powerful source of self-efficacy (Alderman, 2004). On the other hand, a previous failure at a task can severely decrease self-efficacy, especially if the student attributes the failure to lack of ability (Alderman, 2004). If the student attributes the failure to something they feel that they can change, such as lack of effort, their self-efficacy for the task is less likely to be affected. This demonstrates that it is not the sources of self-efficacy themselves which directly affect self-efficacy; it is the individual’s interpretations of these experiences (Bandura, 1997). Vicarious experiences involve observing others model the task that needs to be performed, and then estimating one’s abilities in comparison with those observed. This is most effective when the individual believes they have comparable capabilities with the model they are observing. For example, seeing an expert mathematician complete a problem with ease will probably not have a positive effect on a math student’s self-efficacy. Seeing a peer successfully complete the problem after some difficulty will be more likely to increase the student’s self-efficacy. Verbal persuasion involves others both encouraging and discouraging the individual in their ability to complete the task. Verbal encouragement is most effective when the individual already has some confidence (Alderman, 2004). Negative verbal persuasion is more likely to have an effect of self-efficacy than positive (Alderman, 2004). Physiological and affective states refer to the effects that physical responses to stress and anxiety have on
self-efficacy (Bandura, 1997). Sweating, a rapid pulse, and other physical manifestations of anxiety may be interpreted by an individual as evidence of low ability, and cause a decrease in self-efficacy. Others may experience an increase in energy and self-efficacy due to their physiological states.

Enactive mastery experiences are traditionally thought to be the most influential source of self-efficacy (Alderman, 2004; Bandura, 1997); however, there is no evidence that this is the case for education students learning science content and science pedagogy methods (Palmer, 2006). Palmer (2006) investigated the relative influence of sources of self-efficacy on education students’ self-efficacy for science teaching in a science methods course.

Based on previous research, Palmer proposes that there are additional sources of self-efficacy for education students in a science methods course that do not fit into the four main sources described by Bandura. These additional sources include cognitive content mastery and cognitive pedagogical mastery. Cognitive content mastery is an experience involving understanding science content. This is different than Bandura’s enactive mastery because it involves success in learning content rather than success in teaching science. Palmer considers this a possible source of self-efficacy since many education students do not feel confident in their ability to understand science content. Therefore, successful experiences in learning content may increase a student’s self-efficacy for teaching science. Similarly, students often have not experienced positive role modeling of science teaching. Therefore, learning about effective ways to interest and involve students in learning science can increase an education student’s science teaching
self-efficacy. Palmer refers to this experience as cognitive pedagogical mastery for science teaching.

Palmer’s research (2006) demonstrates that cognitive content mastery and cognitive pedagogical mastery are at least as important in increasing pre-service teachers’ self-efficacy toward science teaching as enactive mastery experiences. This is an important discovery for teacher educators, who must integrate these types of experiences into their courses.

Teachers’ self-efficacy regarding a topic is related to their opinions of its importance and how hard it is to use (Bitan-Friedlander et al., 2004). Extensive research (Donovan et al., 1999; Bleicher & Lindgren, 2005) has shown that in order for pre-service teachers to have confidence in teaching authentic science, they must have successful experiences learning it. If teachers do not have feeling of self-efficacy toward a certain teaching method, they will not be likely to use it (Bitan-Friedlander et al., 2004) and will avoid it (Bruning et al., 2004). Perceived self-efficacy toward a topic or method of instruction not only increases the likelihood that the student will use it, but contributes significantly to performance and achievement (Bleicher & Lindgren, 2005).
CHAPTER III

OVERVIEW OF THE STUDY

1. Participant Profiles

Participants in this study are the twenty one students who enrolled in Everyday Physics in the Spring Semester of 2006. On the first day of class, students were asked to sign a form indicating whether or not they gave their consent for the instructor to use materials generated in this course for purposes of dissemination (See Appendices A and B). The students were not given any evaluation incentives to sign the form. All of the students gave their consent.

Out of the 21 students, all except one planned on teaching science in middle or secondary school. This student had decided before entering the class that she did not wish to become a teacher, but planned on finishing her degree in Education anyway. Most of the students had little science background; not having taken science since high school or having taken one college level course. A few students had taken more than one college level course, and one had a Bachelors of Science in Physics.
2. Course Structure and Instructional Methods

This course was taught through inquiry-based lab activities intended to help students learn the fundamentals of physics as well as how to teach them. It “did not follow the standard practice of teaching physics as compartmentalized independent topics, but used a holistic viewpoint” (Appendix C). Students were made aware that they were expected to take an active role in their learning. Besides learning the concepts and processes inherent in fundamental physics, students would develop “skills that are transferable across disciplines, including group work, verbal and written communication, problem solving, and teamwork” (Appendix C). Students worked in randomly assigned cooperative learning groups during each class, for the entire session.

Since the purpose of inquiry instruction is not to transmit factual knowledge, typical assessments (tests) are not appropriate. Assessment should be of the results of investigations and of the groups’ efforts. (Arends, 1997) Assessment was based 50% on students’ in class work, and 50% on out of class work. In class work was evaluated on engagement in scientifically oriented questions, effort put forth in designing and completing investigations, group participation, and communication and justification of proposed explanations. Out of class work such as lab reports was evaluated based on the scientific review process, which was discussed in depth (similar to White & Frederiksen’s (1998) Criteria for Judging Research).

The class met two times a week for 15 weeks. There was a total of 29 class sessions. Each session lasted for two and a half hours. Students typically completed one or two activities per session, although the schedule was flexible. If an activity took
longer than expected, students continued to work on it during the next session. For each new activity, students were randomly placed in eight groups of two to three students. At the beginning of most class sessions, students were asked to respond to a few prompts in their journals (See Appendix D).

There are multiple functions of this journaling activity. Journaling facilitates student reflection on the previous day’s activities, as well as the course as a whole and how it is affecting their learning processes. It also serves as a valuable source of feedback for the instructor. Beginning the day with reflection makes our schedule slightly different than the inquiry schedule proposed by Arends (1997). By waiting until the next class session to reflect, students were given adequate time to “digest” the experience.

After completing their journal entries, students would be oriented to the problem that they would be working on. For some of the activities, students filled out engagement sheets which explored a student’s prior knowledge on a topic and aimed to engage the students’ interest. For example, before an investigation of torque and equilibrium, the students were asked to define “balance”. After engagement, the instructor discussed the problem being investigated and what materials were available. Students were encouraged to be creative and ask for any materials they thought would be helpful. For each activity, students were given a handout which described the objectives of the activity, explained the problem, and asked leading questions. After reading the handout, students participated in investigation and discovery. During this stage, the instructor and assistants went to each group and observed the investigation, offering guidance through leading questions about the students’ methodology, theories, and conclusions.
Occasionally, several of the groups would find themselves faced with the same dilemma. In this event, the class was brought together for a discussion of the problem, and students were encouraged to offer solutions.

If one of the groups finished before the others, they either went on to the next activity or spread out to help the groups who were still working. The groups generally finished around the same time. When everyone was satisfied with their investigations and conclusions, the class would come together for a discussion of the results. Each group explained their conclusions, as well as the methods they employed during investigation. The instructor then provided a discussion about the experiment and the scientific concepts and processes involved.

For one of the activities each week, students wrote an in-depth lab report. Other out of class work included short homework assignments intended to prepare them for the coming activities, and essays on topics such as historical achievements in science and environmental science.
1. Function of Journaling

During the thirteenth class session, students were asked in a journaling prompt to explain what function journaling served for them in the class. Since the students were all upper level education majors, they had learned about the theory of metacognition in their education classes. We hoped, therefore, that they would link this theory of metacognition to the journaling activity. Eight students out of 21 said that journaling served as a way for them to engage in metacognition, referring to metacognition explicitly. Some student responses referred to metacognition implicitly:

“[Journaling] helps me verbalize my ideas and scientific concepts. It’s one thing to understand a concept, but another to explain it. So journaling helps me with the explaining, which is very valuable as a future teacher.” – Day 13, Student 10

“Journaling helps to focus thoughts and ideas.” – Day 13, Student 15

“The function that journaling serves for me is being able to put my ideas of learning down on paper and think about things I would not have normally thought about if it weren’t for the journaling.” – Day 13, Student 16
“Journaling allows me to look back at how we are being taught in this class which allows me to think about what will work and not work when I have the opportunity to teach.” – Day 13, Student 17

“Journaling in this class helps me connect the physics I am learning to education practices. It also relaxes me.” – Day 13, Student 19

Although none of these students specifically referred to the practice of metacognition, this is what they are explaining in their responses. They explain the process of gathering ideas and concepts and explaining them in their own words. One student believes that journaling leads them to think about things in a deeper way, indicating that journaling facilitates higher order thinking. Another important process that the students engage in is linking the physics learned in class to education practices.

Communication between instructor and student is another function of journaling that many students referred to. Seven students said that journaling served as a communication link between the student and instructor. For example:

“The journaling I really like. I feel I can let myself out on here w/out any hard feelings/lowering in grades. It also helps and has helped me to better understand myself and how I think.” – Day 13, Student 9

This student recognizes the metacognitive benefits of journaling as well as the communication aspect. Students feel they can make comments about the course or ask questions without having to worry about damaging the student-instructor relationship. This is very important for the classroom environment. Inquiry-based classrooms should be open learning communities where no ideas or questions are deemed ‘not good enough’ (Arendts, 1997; Hammer 1995). Journaling provides students with an avenue to ask questions or relate ideas that they would not be comfortable expressing in normal circumstances. By responding positively to the students’ journal entries, we hope to
increase the intellectual safety of the classroom. Students will realize that they will not be punished for any idea or question, and will be more likely to constructively participate in the inquiry process.

2. Attitudes about Science

According to Smith and Anderson (1999), pre-service teachers are often fearful of and intimidated by science learning. They have been taught by their science teachers to view science as a static body of factual knowledge, unrelated to the real world (Norvilitis et al., 2002; White, 1993; Pressley & Woloshyn, 1995). Students will not become excited about science if their teachers are uncomfortable with the subject. If pre-service teachers do not learn to view science in a different manner, this is the perspective they will pass on to their future students, who will then internalize it (Pressley & Woloshyn, 1995). One of the goals of this course was to break this cycle and teach students a different way of thinking about science. According to Drayton and Falk (2001), “Science is not about right answers… Scientific knowledge does not reside in facts but in the shifting web of explanatory theories that provide meaning to humanity’s endless questions.” We wanted to show students the “big picture” of science as a process; as a way to make meaningful discoveries about the world around them. We also wanted students to see that science does not require complex, expensive equipment, but can be taught with everyday items. This section focuses on students’ reflections about science and how their opinions changed over the semester.
During the third day of class, students were asked what they thought the attributes of a good scientist were. At the next session, they were asked if they saw themselves as having these attributes. Student 2 wrote this in her journal:

“In some regards I do relate a lot to the attributes found on the other page [student’s list of attributes of a good scientist]. More times then not, I am willing to make mistakes. Because, how do you learn if you try to reach perfection on the first attempt. I am also willing to experiment to try something new and see what I can learn from it. However, I don’t think I will ever be as smart as a “scientist” because I don’t think I will ever find the cure for many deadly diseases, like some scientists are on the verge of.” – Day 4, Student 2

In this student’s list of attributes of a good scientist, she did not list intelligence or brilliant discoveries as required attributes. However, when asked if she has the attributes she listed, and realizes that she does, she adds the qualifier that scientist must have a certain degree of intelligence that she does not possess. She seems to see scientists as reaching levels that are unattainable to her, and therefore cannot see herself as a scientist.

One student, Student 5, stated that the class was a waste of money and that she “hates the inquiry method.” When asked if she felt that she had the attributes of a good scientist, she stated; “I am curious. But I’m easily frustrated and generally unobservant/oblivious. I’m a Watson, not a Holmes.” – Day 4, Student 5. By referring to Watson, this student implies that she sees herself as an ordinary person, who, although intelligent, does not have the insight and analytical abilities of Holmes. Good scientists, therefore, are not average people, and need not only above average intelligence; they also need to have brilliant insight. She felt that she did not have these qualities. Similarly to Student 2, she stated that she does have some qualities of a good scientist (such as
curiosity), but added that she does not have all the necessary attributes. Again, the qualifier is added, implying that she could not be a good scientist.

Some students attest to the fact that they had negative opinions about science or physics when they started the class, but also that these opinions changed over the semester. For example, on the 27th day of class, student number 14 reflected on the course as a whole:

“This class was the first physics class that I had ever taken. My thoughts about physics before this semester and following the first couple weeks could be summarized by simply saying “yuck”. With 2 classes remaining, it’s safe to say I no longer think that way… I learned that physics can be incorporated into any topic. I learned that class does not have to be taught the traditional way for students to learn.” – Day 27, Student 14

This student was able to change his opinion of physics over the course of the semester. The fact that this student admits that he had a negative attitude toward physics not only coming into the course, but also during the first few weeks of instruction, is very revealing. It highlights the fact that inquiry learning is not a method that can be internalized immediately. Students must learn how to proceed with investigations on their own, which is not an easy task. Similarly, Student 14 commented on the 18th day of class that “it takes some adjustment of my learning styles to learn the material as it relates to physics” and later added that “This is the first science class I’ve taken that I enjoyed coming to.” From the above statements, we can see that these students learned to think of science as a process, instead of a set of facts.

On the fourth day of class, Student 19 expressed apprehension about her ability to practice science and also lack of confidence about scientific knowledge: “Science is not something that comes easy for me…I also don’t feel confident about what I know.”
Toward the end of the semester, she commented on how her feelings about science had changed:

“In the past, sometimes I felt inferior in my science classes. I didn’t know everything and I wasn’t the smartest. This class b/c has taught me that science is a continual learning process, you keep working and working on projects. Sometimes there isn’t a known “right” answer. This has increased my confidence to teach students, because I don’t feel like I need to have all the answers to everything, but that I can guide them into understanding science and we can learn together in our own experiments and labs.” – Day 24, Student 19

This indicates that she has changed her view of science as a body of knowledge that teachers should have memorized and ready for regurgitation to a learning process through which teachers can guides students to discovery.

As stated above, one of our goals was to show students that they could teach science in their future classrooms with inexpensive equipment. Many teachers do not have a large budget for equipment, and think that this means they cannot perform many scientific experiments with their students. Some students expressed surprise that our activities did not require expensive lab equipment:

“I thought science always required formal experiments with fancy equipment – I didn’t know simply using common sense or basic equations could lead to knowing what the chance of hitting a marble in a certain size box would be.” – Day 9, Student 7

“NO BOOKS – but I’ve learned more so far than in any other science class. Real life experience – I could actually repeat these activities someday as opposed to some of the chemistry and biology labs which require expensive equipment.” – Day 18, Student 7

“I think it has just made me put every daily task to the forefront of my mind and think about it differently. I’ve always known that a lot of things we do are “scientific” and can be made into interesting lessons and experiments, but actually doing it has helped.” – Day 9, Student 9
Student 9 states that she knew academically that everyday materials could be used in science experiments, but could not have implemented these in her future classroom without learning how to do it herself.

Besides students changing their views about what equipment is necessary to perform scientific experiments, students also changed their views about how science can be taught and learned:

“Doing these inquiry based labs has changed my views about how science is done. I always thought that inquiry based learning took too long and students didn’t get enough out of it. I now know that it is one of the best ways science is done. It has made me really look forward to teaching science.” – Day 24, Student 16

“My view of science has changed as a result of this class. It can be fun. With the activities and working in groups the concepts are easier to understand. Most science classes I’ve had in the past are lecture based, this one is activity based. That is a great way to show students science can be fun.” – Day 24, Student 10

“I used to believe that science should be done by labs that are written out with step-by-step instructions. After doing the labs in this class and feeling what its like to experience a new idea first hand, I have realized that science is accomplished through experiences… This, I have realized, is how science should be learned.” – Day 24, Student 20

Although these students had been taught that inquiry-based learning was an effective way to teach science in their teaching methods classes, many still did not feel that it was a practical method. After being able to experience this method themselves, the above students realized that inquiry learning can be practical, fun, and exciting. They realized that science does not have to be taught in a lecture environment or with cookbook labs, but can instead be an experience of true personal discovery. Students also learned that there is not one right way to do things and that science is not about right answers; “With all the different ways of completing stuff and ways to go about things, I have better
understood that there are always more answers than just one correct one…” – Day 9, 
Student 3

3. Reflections on the Inquiry Method

Students expressed both negative and positive opinions about the inquiry method 
of the class. This method of learning is very different from what the majority of the 
students were accustomed too. Some students adjusted quickly to the new approach, or 
took a few weeks to adjust, and were able to gain experience and depth of knowledge 
from the class. Other students did not think the methods were successful for them, and 
their opinions remained the same through out the semester. The most common complaint 
was that there was not enough of an introduction to a topic. Thirteen out of the 21 
students specifically stated that they would like more of an introduction to each of the 
topics or more background information before starting an activity.

“I don’t like how we’re just thrown into doing a lab without going over terms, etc. 
If someone didn’t know anything about physics I think that they would be lost or 
very frustrated in trying to learn physics by constantly doing labs and having to do 
their own research for lab reports!! They should be given background knowledge 
first before given any experiment, so that they understand what they’re doing and 
why!” – Day 13, Student 1

This student expresses the opinion that, without background knowledge, students cannot 
understand the purpose or significance of activities. Statements like the one above 
indicate that students are not satisfied with the inquiry method. They have been oriented 
to the problem, as described in the first step of inquiry-based instruction by Arends 
(1997), but they want more than orientation. Near the end of the semester, Student 8
expressed that she wanted more introductory knowledge of concepts: “I feel you should first explain the concept and then do the experiment… When you don’t provide us with knowledge about the concepts we are looking for in our labs, we often feel lost.” However, the point of inquiry-based instruction is to guide students to discover concepts for themselves, not to provide them with knowledge and then ask them to verify it through experimentation (Drayton & Falk, 2001; Zion & Slezk, 2005).

Three students said that they were satisfied with the level of introduction and discussion given and would not change it. Four students did not specifically say if they were satisfied with the level or not. One student initially stated on the sixth day of class that he would like more of an introduction to the topic being investigated. Later, on the thirteenth day of class, he said:

“For me it seems like we are doing a lot of experimenting before learning the actual physics. This allows me to try to figure out the physics on my own so that then when the actual physics is explained it makes more sense. I think investigating a particular subject matter first, allows you to really think and figure things out for yourself, that then allows you to remember it longer.” – Day 13, Student 17

For this student, the inquiry method was successful. Although it took the student a few weeks to adjust, a common theme among students, when he did, he was able to discover scientific knowledge with his peers, instead of learning it through didactic instruction. One student remarked at the end of the semester:

“I don’t think I have had to struggle in a class until this one. In a good way. I just have to find ways to understand everything. The class is taught in a different way and I was not used to it and the more I do the more I learn.” – Day 27, Student 13.

The method of instruction is much different than what students are used to; many students stated that this was the first inquiry-based class they had ever taken. According
to the social constructivist theory, it takes learners time to internalize cognitive changes (Bruning et al., 2004). This can explain why it took students a few weeks to acclimate to the methods of the course.

Although students were oriented to each problem or activity and given objectives, not all students understood the reasons for doing certain activities. For example, on the thirteenth day of class, Student 12 stated that “I do experiments but I don’t know why – other than just do it.” Unlike the students who wanted more introductory content knowledge than the inquiry method dictates, this student’s response indicates a failure on the part of the instructor to properly orient students to the problem. Not all students felt this way. Many students expressed that the course provided them with meaningful learning.

“My experience in this class is positive compared to some of my other classes I have taken. Some of the other classes had no point to why I was learning them, just busy work, but this class I can see why we do some experiments and how we can apply them to when we teach.” – Day 18, Student 13

This student had a reaction opposite to the reaction that Student 12 had above. One source of differing opinions may be the students’ goals in the class. Student 13 stated that she felt she could use the activities when she taught. If students are focusing on gaining teaching methods and inquiry processes, they are more likely to see the purpose of experiments. On the other hand, if students have the goal of gaining a broad base of factual knowledge, they may have a more difficult time seeing the reasons for engaging in the inquiry activities.

Some students expressed dissatisfaction with the amount of content knowledge they felt they were learning. For example, when asked to rank this course in comparison
to other courses (see figure 1), Student 2 stated; “it ranks low in comparison to the amount of material that I carry with me and retain” (Day 18). In response to the same question, Student 8 stated that:

“My satisfaction in this class is lower than in other classes. I feel like I need more concrete knowledge from this class. I would like to see more explanation and discussions, and less inquiry.” – Day 18, Student 8

One possible reason that students may feel uncomfortable with this course is that inquiry learning teaches science as a process, not a list of facts. It is much more difficult to quantify or track the development of this type of knowledge. Another reason that students were preoccupied with gaining concrete, factual knowledge rather than conceptual, process oriented knowledge is that they were concerned with being able to pass the PRAXIS II, a multiple choice subject test for teacher candidates. The test covers mainly factual information, as it is difficult to test authentic learning in a multiple choice format. Student 8 expressed anxiety that she was not gaining the amount of factual knowledge necessary to pass the test. Student reflections indicate that students who were more concerned with passing the PRAXIS II were less satisfied with the course and its methods than students who were more concerned with learning a way to teach science.
Several students stated that the course was too frustrating. Students seemed to feel that if they got frustrated, that meant the learning method wasn’t working for them. However, scientists in the field are often extremely frustrated by their work. The nature of science, having no one right way to do things and no one right answer, can be very frustrating. On the eighteenth day of class, Student 9 said that, “I get more frustrated and more apathetic about this class than any other I’ve taken.” Frustration by itself does not have to be a negative learning experience. Apathy, however, implies that the student is frustrated to the point that she feels there is no point to continue putting forth effort. This is a negative outcome that we try to avoid by instilling students with the belief that they are capable of making discoveries themselves, even when it is frustrating.
Some students realized that frustration can result in great feelings of achievement when a problem is finally understood. For example, on the twentieth day of class, Student 18 observed that “Inquiry is more frustrating, but in the end you can learn more.” Similarly, on day 18 Student 6 said, “It is the most frustrating class I have ever taken. I like what I am learning though.” Student 20 stated on the 24th day of class that, “The feeling that is experienced when something is understood is amazing.” These students realized that although the inquiry method is often frustrating to students, it also facilitates deeper learning and satisfaction. Any method of instruction that results in a greater depth of knowledge requires a lot of effort on the part of the student, and this often results in frustration. We believe that frustration can lead to great feelings of accomplishment, and cannot be avoided in an in-depth learning experience.

Many students realized that they would retain what they learned for a longer time than if they had not discovered it themselves.

“I would rate my experience in this class pretty high. This is the most involved I’ve been in my learning. I think in the future when I need to brush up on material I’ll remember learning the concepts taught in this class.” – Day 18, Student 10.

“With inquiry based learning, a person brings more perspective with them, and the information will be more deeply processed, allowing for longer retention.” – Day 24, Student 4

These statements are consistent with the expected benefits of inquiry-based instruction. When students are involved in their learning and have ownership, they are more likely to retain what they learn.
Students 7 and 19 both took and subsequently dropped traditional physics classes. In this course, they were each able to learn science in a meaningful way through inquiry that was not possible through direct lecture:

“I took a “normal” physics class last semester and dropped it. Although I had memorized some formulas, I had no clue what they meant and when they should be used. When we do the short critical thinking exercises, and have to come up with formulas to solve a problem, we look at the info we have and how we can use it to get our answer. So instead of being given a formula and having to plug in numbers, we are given “ingredients” and have to put them together correctly.” – Day 13, Student 7

“I think the methods used in this class are conductive to my learning physics. I took a physics course that I got half way through and didn’t understand a thing because it was all lecture and bookwork and no application. This class has helped me apply the science methods to different situations and experiments. From this I have learned more because I have had to come to the conclusions myself rather than just copying down the laws of physics (and then not knowing what they mean) I am happy with how much I have learned so far in this class even though it requires a lot of work.” – Day 13, Student 19

These students were able to learn the method of problem solving, and understanding the process and meaning, rather than memorizing formulas. Many students commented on similar successes in their learning due to the instructional method:

“I learn the most when I get to do it or figure it out myself.” – Day 5, Student 20

“…I learn best by doing it myself, this way I make a personal connection with it.” – Day 5, Student 19

“This class has also been one of the best learning experiences I have had because I have learned to think like a scientist… It teaches you a lot about everyday life concepts.” – Day 17, Student 16

“It is nice because in many ways I am teaching myself but at the same time he is setting up the experiments and assignments to answer my questions.” – Day 17, Student 17

“We spend time experiencing science and physics which helps you learn the material better than bookwork and lecture.” – Day 17, Student 21

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“[The instructor] cares about what we learn, and how we learn physics, and he uses creative but challenging ways of “teaching”. This class has taught me how to learn to learn.” – Day 18, Student 19

These reflections indicate that the instructional methods were successful in their goals to teach science as a meaningful process rather than a set of facts, and students were able to construct learning experiences on their own; therefore taking ownership of their work.

“This is the first class I have had that has been based on inquiry learning. At times I find this frustrating, but in the end when I’m done with a project it is awesome because I learned so much on my own through research and discovery, rather than just learning by copying notes from lecture. I want my students to experience this feeling of accomplishment in learning science through inquiry. I believe I learn much more from inquiry learning than from copying notes off the board because I make the knowledge my own and not somebody else’s.” – Day 11, Student 19

4. Predicted Impact on Future Practice

On the twenty first day of class the students performed an experiment on effervescence. The experiment was written up in two ways; as a guided inquiry activity and as a traditional lab activity (See Appendices E and F). Students were put into groups, and each group was randomly assigned to work on either the inquiry or traditional version of the activity. Eleven students performed the traditional version of the experiment, eight students performed the inquiry-based version, and two students were absent that day. After performing the experiment, each group summarized what they did and reported their results to the class. Students were given a copy of both lab write-ups to compare.
During the next class, students were asked; if they had a choice of which version of the lab to do, which they would choose (see figure 2). Thirteen students said they would choose to do the inquiry-based version. Six would have chosen the traditional version. In an attempt to rule out the possibility that students were influenced in their decision by which lab they had personally done, we compared the version performed with the version chosen. Ten students would have chosen a different version than what they had done. Nine students would have chosen the same lab that they did. Since almost 50% of the students chose to change (or not change) their version, we can conclude that the students were not biased for or against the version that they performed.

Figure 2: Student responses to the journal prompt given on Day 22: "If you had your choice of which version of the effervescence lab to do, which would you choose and why?"
The reason most commonly given for choosing the traditional version of the activity was that students liked the step-by-step aspects, and preferred to know exactly what was expected of them: “With school and work, I like directions. That way, I know what is expected of me and how to reach that point.” – Student 3, Day 22. Some students indicated that their choice was influenced by the point in the semester: “If the activity had been done at the beginning of the semester I would have chosen discovery lab. After 10 weeks of brain drain I was glad to have some direction and just do the experiment.” – Day 22, Student 15

Interestingly, the fact that the inquiry version was seen as more challenging is given as a reason for both choosing it and not choosing it. The above student was ready for a break from the work that comes with inquiry. However, many students stated that they preferred the inquiry version as it was more interesting and challenging:

“I liked the one I did (effervescence lab using inquiry). I like coming up with predictions and making a hypothesis and then testing it. It made me think a lot harder about what variables needed to be controlled. I feel like I accomplished more with this type of lab than if all the steps would have been written out for me.” – Day 22, Student 19

“Anyone who can read can follow specific instructions. It takes higher order thinking to develop, test, and explain solutions to problems.” – Day 22, Student 14

Students also chose the inquiry version because they preferred the freedom that came with it.

In addition to asking students which version they preferred to do themselves, we asked them which version they would choose for their future students (see figure 3).
Figure 3: Student responses to the journal prompt given on Day 22: "If you had your choice of which version of the effervescence lab to give to your students to do, which would you choose and why?"

Nine students said they would use the inquiry version in their classrooms. Reasons given for choosing the inquiry method included wanting to challenge their students and also being interested in how the students would choose to perform the lab:

“I have high expectations of my students. They’ll learn more this way than they will by me telling step by step instructions, force feeding them information.” – Day 22, Student 13

“I like the inquiry based idea for this project because I am interested to see the different ways my students will go about this lab.” Day 22, Student 3
Two students said they would use the traditional version because they did not think their students would know how to do the inquiry lab and because they thought the traditional version would keep students on task.

Eight students said they would use a combination of the inquiry and traditional versions. These students said that they wanted their students to be able to do certain things from the inquiry version, such as design a hypothesis or control variables, but thought that their students might need more guidance than was given in the inquiry version. Most of these eight students also said that which version they used would depend on their particular class. The grade level of the students was seen as an important consideration. Three students said that they would use the traditional version in younger grades and the inquiry version in older grades. Two students also said that during the beginning of the school year they would focus on the traditional version, but later in the school year, after the students had gained experience in performing activities, they would use the inquiry version.

It is interesting that several students chose a different version for themselves than they did for their students. Students who chose inquiry for themselves and either traditional or a combination for their students seemed to value the inquiry experience but doubt that their students would be capable of completing it. Students who chose traditional for themselves and either inquiry or a combination for their students also seemed to value the inquiry experience for their students, but did not want to put forth the effort necessary themselves (see Student 15’s comment above).
When students were asked if they would use or adapt the activities, methods, or approaches from this class for use with their future students, twenty out of the twenty-one students said that they planned on using inquiry methods in their future classrooms.

“This has provided me the opportunity to review and develop this model of teaching, which I strongly endorse, and provide examples of ways in which I can present these concepts to my future students. I appreciate the simplistic way the concepts were presented using real world materials of which the students can relate. This helps them understand the concepts better and provides further examples of how to communicate this to the students. Basically, this class has functioned as a template from how I wish to teach.” – Day 27, Student 21

“I know that I can do most of these labs we did and convert them to my classroom… As a teacher, I can look back at this class and use ideas from here or remember what I can do for a lab. There were so many times I walked into this classroom with a negative attitude but all my experiences from this class are positive. And I will walk out of this class at the end of the semester feeling positive about physics and being a teacher.” – Day 27, Student 13

“Not only did I learn some physics, but more importantly, learned a style and approach to teach physics… When I have my own classroom, the impacts from this class will be seen through my instruction and style of delivery.” – Day 27, Student 14

Some students planned on using the inquiry methods regularly in their classrooms, whereas some planned on using the method as a break from traditional instruction.

5. Self-Efficacy for Teaching and Learning Science

Students were asked on the 9th and 24th days if this class increased their level of confidence in their ability to teach science (see figure 4). On the 9th day, 12 students said that the class had increased their confidence, two students said that their confidence had increased somewhat, and seven students said that they did not feel confident in their
ability to teach science. On the 24th day, 15 students said that the class had increased their confidence, four said that their confidence had increased somewhat, and two said that their confidence had not increased. The increase in students who felt more confident from Day 9 to Day 24 supports our previous assertion that inquiry and constructivist learning require an adjustment period.

![Changes in Students' Confidence in Their Ability to Teach Science](image)

Figure 4: Student responses to the journal prompt given on Days 9 and 24: “Provide any evidence that you have that this class has increased your level of confidence in your ability to teach science.”

Some students did not feel that the course was effective, even after an adjustment period:

“I’m still where I’m at when I started this class, still really not understanding much about physics, so my confidence level in teaching physics is pretty low… However, I’m more confident in trying to figure out how to do things and figure out the meaning behind it.” – Day 24, Student 1
This student does not feel confident in her ability to understand physics, and therefore has low self-efficacy for teaching physics. Interestingly, she notes that she is more confident figuring out how do to things and figuring out the meaning, both of which are process skills. Her statement implies that she was able to increase her self-efficacy for performing scientific processes, but not for understanding content knowledge.

The reflections of most of the students indicate that the course was successful in increasing their self-efficacy for learning and teaching science processes and content.

“I dropped out of the other physics class last semester – I felt hopeless and considered changing my area of concentration [science]. Now, this is my favorite class and I look forward to it.” – Day 9, Student 7

“I have written lab reports on topics that I would have been terrified to take on a few months ago.” – Day 24, Student 7

This student was able to dramatically increase her self-efficacy for learning science.

Although she does not directly mention a change in confidence levels for teaching, the fact that she is no longer considering changing her area of concentration indicates that she feels she will be able to be a successful science teacher. This is an example of Palmer’s (2006) cognitive content mastery experience. By increasing her confidence in learning content knowledge, this student was able to increase her self-efficacy for future teaching experiences. The following students directly refer to content knowledge as a source of self-efficacy for teaching:

“I can describe and discuss physics concepts such as displacement, terminal velocity, resonance, sound, energy displacement, dimensional analysis (somewhat), 1 electric currents, flow of energy, and much more. With the knowledge and skill of being able to graph data on excel my students will be able to analyze relationships through terms of the graphs. So, this has also increased my knowledge and confidence in teaching and learning science.” – Day 24, student 11
“This class has increased my confidence to teach science because I have learned through these 24 days. I could look at something moving at high or low frequency and tell you why the salt isn’t moving on the plate. I can also tell you that a magnet can move aluminum even though it’s not magnetic, it’s because of your hand and the magnetic field around the magnet and aluminum. The energy is coming from your hand. All the things that I have learned in this class, I can apply.” – Day 24, student 13

Another student was able to increase her confidence through a combination of cognitive pedagogical mastery (Palmer, 2006) and vicarious experiences (Bandura, 1997). The vicarious experiences in this course were not direct because the students were observing a model involving inquiry-based science teaching of college students, not of middle school students. However, since students felt that this model can be adapted to their future classrooms (as discussed in the previous section); the vicarious experiences can be a strong source of self-efficacy. This student had learned about inquiry learning in her methods courses, and understood its value. However, she needed to see it in action to truly understand the method and feel confident in her ability to use it:

“I’ve been taught to use inquiry based science in my future classroom. I had never experienced inquiry based science in the classroom. This class has given me confidence (which I already had) that I didn’t know was lacking because I have now seen the method in use.” – Day 9, Student 4

This change in confidence levels will likely affect this student’s future teaching. Previously, she may have planned on using inquiry in her classroom. However, without experiencing it first hand, she would have had a difficult time implementing it. This disconnect between theory and practice is overcome by combining content and pedagogy.
One student was able to use his experiences in the classroom to create his own enactive mastery experience. By increasing his self-efficacy for inquiry-based teaching in Everyday Physics, he was able to successfully use the method in a field experience:

“I believe that this class has helped me a lot in inquiry based teaching because I had to teach an inquiry based lesson last week. At the beginning of the semester I was very nervous about teaching that lesson. By taking this class I taught that lesson with confidence and enjoyed it.” – Day 24, Student 16

Like Student 7 (see above), Student 19 had previously taken and dropped a traditional physics class. She came into Everyday Physics with very low self-efficacy for teaching and learning science. Also like Student 7, she was able to overcome her fear of science and embrace it:

“Last semester I started to freak out thinking “What if I can’t teach science? I feel like I don’t know a lot, like math!” This class has instilled in me the confidence I need to teach science. I now see science as exploration, on going, fun, and challenging instead of a teacher standing up in front of the class and rattling off everything they know. I hope I can help students see the challenge and feeling of accomplishment that science discovery, exploration, and inquiry brings. Now, I am excited to teach science!” – Day 27, Student 19
Teaching science to students through inquiry-based instruction and problem-based learning can be a benefit to our society. It is proven to be an effective method for learning the process of science discovery. However, unless teachers experience this type of instruction first-hand for themselves, it will never be successfully implemented in the classroom, at least in widespread form. Everyday Physics is a physics content course for education majors, which gives students extensive experience with inquiry-based science.

The experience gained in Everyday Physics changed many students’ opinions about what science is and how it is done. Some students came into the class thinking of science as a list of facts or as requiring expensive, complex equipment, and were able to gain a view of science as a process which can be investigated with simple, everyday items. We learned that the extensive experience involved was critical to students’ success in mastering learning through inquiry. This method is quite different from what students are accustomed to, and they are often very uncomfortable initially. After learning science by following step-by-step instructions, it is challenging to learn how to construct one’s own knowledge and understanding. One or two inquiry-based
experiences will not be likely to allay this discomfort; students must have time to adjust
to the new style.

Our data indicate that most of the students in Everyday Physics were able to
increase their self-efficacy for both learning and teaching inquiry-based science. This is a
tentative conclusion, due to the small sample size of 21 students, and the qualitative
methods of data collection.

The data collected here suggests many areas of future research. For example,
during the Spring semester of 2007, students in Everyday Physics were given the
Teaching Science as Inquiry Instrument (Smolleck, 2006) at the beginning and end of the
semester. This instrument uses a 69-item Likert-type scale to measure pre-service
teachers’ self-efficacy for teaching science by inquiry (Smolleck, 2006). By comparing
the data collected at the beginning and end of the semester, we hope to track changes in
students’ self-efficacy. This instrument can be given to future students of Everyday
Physics, increasing the data collected to a significant sample size. It would also be
helpful to track students into their classrooms. We have attempted to predict the impact
of this course on the students’ future instruction; however, it is impossible to know the
true effect without follow-up.

Although most students reported positive results in learning, some students did
not think that they gained enough content knowledge from the class. Based on
observation, it appears that these students were taking the class with the goal of passing
the PRAXIS II, a multiple choice subject test. This is indicative of the fact that inquiry
learning focuses less on factual information, but rather on a greater depth of
understanding. Another area of future research would be to compare student success on
the PRAXIS II test with the method of instruction they received. It would be helpful to see how the students who learned through inquiry performed compared to students who learned through direct instruction.

The students who were more confident in their gained knowledge were taking the class with the goal of learning science content and instructional methods they could use in their future classrooms. Other students who were able to greatly increase their self-efficacy included some students who had previously experienced perceived failures in learning physics. After trying and failing to learn physics through memorization, they were able to gain a greater depth of knowledge through investigation and active learning. They experienced the great sense of achievement that comes with constructing one’s own understanding, and look forward to sharing this with their students.

It is our position that there needs to be more science content classes taught with constructivist or inquiry instructional methods for pre-service teachers. Although pre-service teachers already have methods classes for the sciences, our research indicates that in order to understand how to teach inquiry-based science, teachers must have experience learning science content through this method.
REFERENCES


APPENDICES
APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

Office of Research Services and Sponsored Programs
Akron, OH 44325-2102
(330) 972-7688 Office
(330) 972-6281 Fax

January 12, 2004

Rex Ramster
Physics Department
The University of Akron
Akron, Ohio 44325-4001

Dear Dr. Ramster:

The University of Akron's Institutional Review Board for the Protection of Human Subjects (IRB) completed a review of the protocol entitled "Everyday Physics Team Assessment". The IRB application number assigned to this project is 20040701.

The protocol qualified for exemption from IRB review on January 9, 2004. The protocol represented minimal risk to subjects. Additionally, the protocol matched the following federal category for exemption:

Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior wherein subjects cannot be identified, the risk of civil or criminal liability is minimal, and risk of damage to the subjects' financial standing, employability, or reputation is minimal

If you propose changes to this protocol, an Application for Continuing Review Form must be completed and submitted to the Office of Research Services.

Please retain this letter for your files. If the research is being conducted for a master's thesis or doctoral dissertation, the student must file a copy of this letter with the thesis or dissertation.

Sincerely,

[Signature]

Sharon McWhorter, Associate Director
Research Services and Sponsored Programs

Cc: Devinder Malhotra, Department Chair
    Phil Allen, IRB Chair
APPENDIX B

STUDENT CONSENT FORM

Consent Form  Everyday Physics  Instructor: Rex Ramsier

Spring 2006

Dr. Ramsier does have my consent to use materials that I generate in this course for purposes of dissemination.

Signature  Printed Name  Date

Dr. Ramsier does not have my consent to use materials that I generate in this course for purposes of dissemination.

Signature  Printed Name  Date
Everyday Physics       3650:401/501       Spring 2006

Instructor: Dr. Rex D. Ramsier    office: Ayer 111    phone: (330) 972-4936
4936    e-mail: rex@uakron.edu    fax: (330) 972-6918
6918

Text: None.

Office Hours:

My official office hours are 10:00 – 1:00 on TTh. I have set aside 1:00 – 5:00 PM on TTh for this class, but my office is right next door and I am usually around. I will be in the lab a lot working on developing activities for your class. You should feel free to contact me anytime in person or by email. All students are required to use e-mail capable of opening MSWord and PDF documents to retrieve assignments, announcements, etc.

Overview:

In collaboration with the Center for Collaboration and Inquiry and the Department of Curricular and Instructional Studies, this new course will:

1. Address specific educational needs for science with licensure and generalist students
2. Model collaboration between the Buchtel College of Arts and Sciences and the College of Education

3. Develop and test activities for the Northeast Ohio Center of Excellence and Ohio middle level science (OSCI) teams


This new course will provide students with “all the Physics they will need” in a way that will be useful to them as teachers. Inquiry, discovery, and experiential learning in a lab environment will be the format, including take home activities to extend learning beyond the classroom. Inexpensive and simple equipment will be used as much as possible, in order to provide students with a means of learning physics and learning to teach physics with everyday materials.

According to the standards proposed by the National Science Teachers Association, elementary and middle level general science teachers need to be prepared to lead students to understand many physics related topics, including but not limited to:

- Properties and applications of sound, light, magnetism and electricity
- Potential energy, kinetic energy, and work
- Energy transfer
- Conservation of matter and energy
- Nature of radioactive substances
- Chemical, electrical, and radiation safety.

There are also standards concerning the nature of science . . .

- Historical and cultural development of physics knowledge
- Philosophical issues and assumptions that distinguish science from other ways of knowing the world
- Critical analysis of false or dubious assertions made in the name of science, . . . as well as those concerning inquiry . . .

- Processes and assumptions of multiple methods of learning leading to scientific knowledge
- Developing concepts and relationships from observations, data and inferences, . . . and issues . . .

- Understand socially important issues and the processes used to analyze them and make decisions
- Engagement in cost analyses, problem-solving and decision making.
These standards are intimately connected with the Ohio Academic Content Standards, which provides benchmarks for the physical sciences. Some of the relevant benchmarks include:

- Describing the motion of objects and the forces involved
- Describing the different forms of energy and energy transfer mechanisms
- Understanding light, sound, electricity and magnetism.

There are also science and technology benchmarks . . .

- Citing examples of how technology, influenced by science, affects human life
- Designing a solution taking into account time, cost, trade-offs, material properties, safety, etc.,

. . . as well as those concerning inquiry . . .

- Using instruments to observe, measure, and collect data in a scientific investigation
- Organizing and evaluating data and forming conclusions
- Communicating results in a scientific manner,

. . . and ways of knowing . . .

- Using hypotheses, record keeping, description and explanation
- Understanding reproducibility and reduction of bias.

Course Structure:

This course is dedicated to helping you learn the fundamentals of physics as well as how to teach them. In this context, we will practice skills that are transferable across disciplines, including groupwork, verbal and written communication, problem solving, and teamwork. Laboratory and experiential activities both inside and outside the classroom will be part of this course, and you will need to take an active role and assume responsibility in your own learning. We will not follow the standard practice of teaching physics as compartmentalized independent topics, but will use a holistic viewpoint. It may be difficult at first for you to see the big picture, but it will develop with time. I will need your help and feedback constantly to make this work. We have lab helpers that will be here to assist us as well, and we should all look at this a one big team effort to learn physics and learn to teach physics.

Grading: Your grade for the course will be weighted as follows:
(50%) In class work. This will include your level of participation and responsiveness both during the activities and with the journaling. Also, we will be doing group and team work, and you will be facilitating activities as well.

(50%) Out of class work. This will include research as well as take-home activities, report writing, and the active use of email to communicate back and forth with the instructor.

University Statement:

"Students whose names do not appear on the university's official class list by the 14th day of class will not be permitted to participate."
Journaling Prompts for Everyday Physics, Spring 2006

Note: Students did not journal on days 8, 10, 12, 15, 16, 23, 25, 28, or 29.

Day #1 (1/17/06)
1. Describe what you are good at.
2. What is your favorite song, and why?
3. What types of jobs have you had?
4. Describe your favorite place on Earth.

Day #2 (1/19/06)
1. Describe why you want to be a teacher.
2. Describe the expectations that you will have for your students.
3. Think of the word scientist, and then draw a picture of one.

Day #3 (1/24/06)
1. Describe what you think will be the most difficult part of being a teacher.
2. Explain what attributes you think a good scientist should have.

Day #4 (1/26/06)
1. Last time, you were asked to explain what attributes a good scientist has. Do you see yourself as having these attributes? (Explain)
2. Recall from the past a scientific experiment or discovery that had an effect on you.
3. How do you define a good learner?

Day #5 (1/31/06)
Complete the following statements
1. I learn the most when I…………..
2. In college, I am stressed out most by…………..
3. If I could change one thing about my college education, I would…………..

Day #6 (2/2/06)
Complete the following statements:
1. What I would change about this class is…………..
2. Punxsutawney Phil…………..

Day #7 (2/9/06)
1. Describe one current event that you heard about or read about this weekend.
2. Write the word conflict. Now write all the words or phrases that come to mind that you associate with conflict.
3. How do you feel that the research performed here at The University of Akron has affected your education (pros and cons)?

Day #9 (2/14/06)
1. Provide any evidence that you have that this class has increased your level of confidence in your ability to teach science.
2. Provide any evidence that you have that this class has changed your attitude and view of what science is and how it is done.

Day #11 (2/23/06)
1. Describe what you found useful about the peer tutoring activity concerning the Mozart and Mpemba effects.
2. Do you think that you will use some of the methods and approaches used in this class when you are teaching? Give examples.
3. What do you think of when you hear the term “Urban School Systems”?

Day #13 (3/2/06)
1. Do you think that you will be able to use or adapt some of the actual activities from this class when you are teaching? Give examples.
2. Are the pedagogical methods used in this class conducive to your learning physics content knowledge? Provide examples and reasons for your answer.
3. Explain what function journaling serves for you in this class.

Day #14 (3/7/06)
1. Describe a K-12 teacher that made a lasting impression on you when you were being schooled, and explain why this person comes to mind.
2. Explain what you feel are the pros and cons of getting to know your students on a one-to-one basis.

Day #17 (3/16/06)
1. What do you anticipate will be the greatest challenge you will face in attempting to use inquiry-based methods in your future classrooms?
2. Explain how you would describe your experiences in this class to a friend or relative that never attended college.

Day #18 (3/21/06)
1. Explain how you would rate your experience in this class vs. other classes at UA.
2. Write the words nuclear power. Now write all the words or phrases that come to mind that you associate with nuclear power.

Day #19 (3/23/06)
1. Discuss your feelings about the peer tutoring activity involving polywater and cold fusion.
2. Discuss your feelings about the lab report peer review assignment that you have been given.

Day #20 (4/4/06)
1. Discuss your feelings about the lab report peer review assignment that you just handed in.
2. Discuss what you feel are the differences between learning through inquiry based labs vs. traditional labs.

**Day #21 (4/6/06)**
1. Discuss your feelings about the lab report peer review feedback that you just received.

**Day #22 (4/11/06)**
1. If you had your choice of which version of the effervescence lab to do, which would you choose and why?
2. If you had your choice of which version of the effervescence lab to give to your students to do, which would you choose and why?

**Day #24 (4/18/06)**
1. Provide any evidence that you have that this class has increased your level of confidence in your ability to teach science.
2. Provide any evidence that you have that this class has changed your attitude and view of what science is and how it is done.

**Day #26 (4/25/06)**
1. Give examples of activities done in this class that you will be able to use or adapt for your own students.
2. Give examples of methods and approaches used in this class that you will be able to use with your own students.

**Day #27 (4/27/06)**
1. Take some time to reflect on this class, and write about the experience and its impact on you as a future teacher.
APPENDIX E

GUIDED INQUIRY EF'ERVESCENCE EXPERIMENT

Temperature and Rate of Dissolution of Effervescent Tablets

How does the temperature of water effect the time it takes for an effervescent tablet to dissolve?
Does the dissolution process cause the water to warm up or to cool down?

Materials:

- Effervescent tablets
- Hot water
- Styrofoam cups
- Thermometer
- Stopwatch
- Cold water

Directions:
1. Write a plan that will allow your group to find out the answer to the above questions using only the materials available. Your plan must include:
   - An hypothesis
   - What is to be measured during the experiment
   - How you will report your results
2. Remember to consider and control variables.
3. Summarize your data and write a statement that clearly describes what you found out. These are to be turned in as a group.
4. Be prepared to make a presentation of the results to the rest of the class when called upon.
TRADITIONAL EFFERVESCENCE EXPERIMENT

Temperature and Rate of Dissolution of Effervescent Tablets

You will do an experiment that demonstrates how the temperature of water effects how fast an effervescent tablet dissolves, and how the dissolving process affects the temperature of the water.

Materials:
- Effervescent tablets
- Hot water
- Styrofoam cups
- Thermometer
- Stopwatch
- Cold water

Directions:
1. Group member roles: Tallest person will be the materials manager; shortest will be the data person; others in the group will be the presenter and the clean up person. If you only have three in the group, someone will have the latter two roles.
2. Materials manager gathers materials and does the manipulations with the materials.
3. Place a mark about 2/3 of the way up on one cup. This will be the “measuring cup” and control the amount of water you put in each of the other cups. Fill the measuring cup, to the mark, with cold water and transfer the cold water into one of the other cups.
4. Measure the temperature of the water and record the temperature for five minutes (every 30 seconds) to see if the water warms up very much due to sitting in the room. (data person) This is a control experiment.
5. Open an effervescent tablet pouch and make sure the tablets are not broken or chipped (so that they have (almost) exactly the same mass. Use only uniform tablets in all experiments.
6. Drop two tablets in the water and start the timer.
7. Record the temperature every 15 seconds until all effervescent action has stopped. (data person)
8. Dispose of the solution in the bucket, rinse out cup and re-use. (clean up person)
9. Repeat steps 6-8 until you have used half of your tablets.
10. Fill the measuring cup, to the mark, with hot water and transfer the hot water into one of the other cups.
11. Measure the temperature of the water and record the temperature for five minutes (every 30 seconds) to see if the water cools very much due to sitting in the room. (data person) This is a control experiment.
12. Drop two tablets in the water and start the timer.
13. Record the temperature every 15 seconds until all effervescent action has stopped. (data person)
14. Dispose of the solution in the bucket, rinse out cup and re-use. (clean up person)
15. Repeat steps 12-14 until you have used the other half of your tablets.
16. Clean and dry your work area and thermometer. Return tool box to cart. (clean up person)
17. Make graphs of your data with temperature (Kelvin) on the y-axis and time (seconds) on the x-axis. Make one graph for all the cold water experiments, and one for the hot water experiments. (data person)
18. Answer the following in writing and turn in with your data as a group: A. Did the water warm up or cool down due to the effervescent process? (You need to compare to the control experiments). B. Which dissolved the tablets faster, hot or cold water? (presenter will present to class)