2004

A constructivist approach to integrating science, technology, and engineering into preservice teacher education

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A constructivist approach to integrating science, technology,

and engineering into preservice teacher education

by

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A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Education (Curriculum and Instructional Technology)

Program of Study Committee:
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Iowa State University

Ames, Iowa

2004

UMI Number: 3145640

Graduate College
Iowa State University

This is to certify that the doctoral dissertation of

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has met the dissertation requirements of Iowa State University

Signature was redacted for privacy.

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Signature was redacted for privacy.

For the Major Program

ABSTRACT

This case study examined a cohort of preservice teachers who participated in an innovative engineering course as a major component of their teacher preparation program. This course, used engineering as a context to teach science and technology concepts. The purpose of this case study was to describe the experiences and reactions of a cohort of preservice teachers enrolled in this engineering course. In addition, this study sought to gain a deeper understanding of how preservice teachers described and reported learning in this constructivist based engineering course. Data sources from this study included: classroom observations and interactions, field observations and notes, reflective journals, WebCT postings, project artifacts, and personal interviews.

Major findings from this case study included a deeper understanding of science, technology, and engineering reported by the majority of the preservice teacher participants. In addition, preservice teachers gained and reported more advanced strategies for problem solving, communicating, and working within a course that used a constructivist framework for learning. Results from this study suggest that engineering can provide a valuable context for preservice teacher preparation that involves learning and teaching of science, technology, and problem solving.

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CHAPTER I

INTRODUCTION

In a classroom in the suburbs of Boston, a class of first-graders are designing snow removal equipment out of LEGO Dacta materials. Before breaking up into groups, they are having a class discussion about different types of equipment - shovels, plows, front-end loaders, etc. One boy raises his hand and says "Can we make up something different? I mean, can we just design something that hasn't been made before?" The teacher answers yes, and the boy turns to his LEGO partner and says "We are inventors!" (Erwin, 2001)

Today, more than ever before, technological competence has become crucial to maintaining our nation's position as a leader in global affairs and to solidifying our position in the emerging global economy (Federal Coordinating Council for Science, Engineering and Technology, 1993). Moreover, this situation places special responsibility on American educators to guarantee that students at all levels gain exposure and encompass opportunities to pursue quality science, mathematics, engineering, and technology (SMET) education. In the No Child Left Behind Act particular emphasis was placed on the area of science. During the 2007-2008 academic year, assessment of science comprehension in K-12 classrooms must be underway (U.S. Department of Education, 2003).

To ensure that K-12 students are receiving quality educational experiences in science and technology, teachers must be competent and capable of providing their students exemplary learning experiences; yet many education programs are currently graduating future teachers that are unprepared to teach science and technology. "American students are entitled to teachers who know their subjects, understand their students and what they need, and have developed the skills to make learning come alive (National Commission on Teaching and America's Future, 1996, p. vi). Great teachers have a profound understanding of the subjects that they teach and they work with a firm conviction that all children can learn (Hunt & Carroll, 2003). In addition, teachers know how to use modern technology to support their students' mastery of subject matter content.

While numerous National Science Foundation hands-on, inquiry-based mathematics and science supported instruction projects arose from the 1960's space race, none resulted in producing long-lasting systemic changes (National Science Foundation, 1996). Moreover, the main contributing failure included teacher preparation programs that did produce fundamental changes. Furthermore, K–12 teachers were simply unprepared to work with the new materials. The preparation of teachers in the areas of science and technology needs improvement, and not just on a small scale (National Research Council, 2001). Additionally, there is supported evidence that this situation permeates a great deal of the teacher preparation system and that many educators report frustration with current methods and approaches to teacher education.

As technology is becoming an increasingly important aspect of education and our lives, the absence of the content and processes of one subject has become increasingly evident over all others: engineering (Erwin, 2001). Erwin continues to state that engineering can be a wonderful and fascinating lens through which to look at the world around us and whether it is the rack and pinion in your ice-cream scoop or the processor in your computer, examples of engineering are abundant and everywhere. Engineering should not be viewed as a separate or new subject to be taught in the classroom but rather a context in which to teach science and technology. A nurturing environment that introduces K-12 students to engineering principles and concepts is a classroom that uses a constructivist approach to learning.

According to Gil-Perez et al. (2002), a constructivist approach to learning in a science classroom is an approach that contemplates active participation of students in the construction of knowledge and not the simple personal reconstruction of previously elaborated knowledge provided by the teacher or textbook. Bell and Pearson (1992) add that classroom teachers cannot change what they do in the classroom without first transforming their epistemology and conceptions about how scientific knowledge has constructed their views about science.

The purpose of this chapter is to introduce a research study that examines a cohort of preservice teachers that are enrolled in an engineering course that employs a constructivist framework for learning science, technology, and engineering. This chapter consists of the following six sections: Background, Preparing Tomorrow's Teachers to Use Technology and the Technology Collaborative Project, Statement of the Problem, Purpose of the Study, Research Design and Guiding Questions, and Significance of the Study.

Background

Importance of Science and Technology Education

Education serves no higher purpose than preparing individuals to lead responsible and personally fulfilling lives (American Association for the Advancement of Science, 1990). Moreover what the future has in store for the nation and world depends largely on the wisdom with which individuals use science and technology. The No Child Left Behind Act of 2001 includes making science curricula more rigorous. This bill states that the following have been cited as directly contributing toward this national failure to lead our children toward excellence in both science and mathematics:

- too many teachers teaching out of their field expertise
- inadequate teacher preparation in science
- schools lacking challenging science in curricula and textbooks
- too few students taking advantage of advanced coursework in science
- a lack of current understanding into how students learn effectively (U.S. White House, 2001).

This Act also states that all students need a basic grounding in science to lead both a fulfilling life and to function appropriately in an increasingly complex world. The time is right for focusing attention on producing well-qualified K-8 teachers with strong backgrounds in science. In the next decade alone, our nation's schools will need to hire 2.2 million new teachers (National Commission on Mathematics and Science Teaching for the 21st century, 2000). National models to improve elementary and middle school education teacher preparation in science and an increase in the number of qualified individuals entering the teaching profession are needed.

Engineering As a Context to Teach Science and Technology

From a school's perspective, anything that is viewed as an "add-on" to the current classroom curriculum is bound to be doomed (Stephenson & Johnson, 2002). The authors further state that schools are so overloaded now with requirements including high stake testing that unless something meets a real need, it is likely to be viewed as a frill. To be able to effectively convince educators that they are not teaching an additional subject, if engineering is incorporated into current classroom curriculum, will be the main challenge facing this type of educational reform. Engineering offers an effective context for problem-solving situations. By "engineering context" it is not implied that one should replace existing science, technology, and mathematics curriculum in schools, but rather to enhance the curriculum by incorporating engineering as a learning tool. Rushton et al. (2002), state that teachers need to be able to see how engineering can compliment and tie together traditional classroom curriculum. When teachers are shown how engineering and another content area can fit into existing lesson plans, teachers become more willing to use the material to enrich students' overall educational experiences. For example, when students are learning how to multiply fractions, traditionally they are asked to complete this task using paper and pencil and are learning the rules of fraction multiplication by rote memorization. Instead, with engineering as a context, students can be asked to design a gearbox that would propel a small robotic car up an incline. To complete this task requires students to use several gears with differing gear ratios to become meshed and the gear ratios (fractions) would have to be multiplied to arrive at the machine's overall gear ratio.

Because science and math are both fundamental K-12 subjects taught throughout the world, using engineering as a real-world application of the same principles provides a gateway to creative real-life solutions (Schaefer, Sullivan, & Yowell, 2003). Engineering as a context to teach subjects such as science, math, and technology provides relevance to students, which is often lost in the traditional curriculum (Rushton et al., 2002). Furthermore, this loss has left children and teachers without a rationale for learning, retaining, or valuing the content material. Teachers need to be exposed to the merits of engineering at every level of education to establish tangible connections between engineering principles and real world examples. An instructional approach that has shown promise for both teachers and students for effective teaching and learning of science, math, and technology is the creation of a constructivist environment (Genalo & Gallagher, 2002).

Insufficient Science and Technology Education Preparation for Elementary Preservice Teachers

With the growing influence and increasing complexity of technology, people must possess a certain level of technological understanding to make informed decisions to attain a reasonable quality of life (Gorham et al., 2003). Furthermore, it is crucial that current and future teachers have the resources, knowledge, skills, and support available to empower students to make their own informed decisions as citizens, consumers, and members of the workforce.

According to the 2000 National Survey of Science and Mathematics Education, forty percent of elementary teachers have taken four or fewer semesters of science coursework suggesting that these teachers have not received an adequate background to teach science. And less than one-third of elementary school teachers reported feeling qualified to teach each one of the science disciplines where fewer than 3 in 10 teachers reported feeling well prepared to teach the sciences (National Survey of Science and Mathematics Education, 2000). Because of such statistical data, the trend of paying attention to teachers' knowledge of science topics and the pure nature of science has been triggered in part by this urgent need to improve the quality of science in teacher education (Szekeres, T., & Vasarhelyi, Z., 1998). It is not acceptable that many of the nation's teachers are not adequately prepared to teach science and technology using standards-based approaches and in ways that encourage student learning and achievement (National Research Council, 2001). One way to assist preservice teachers to become adequately prepared to teach in the areas of science and technology is to provide them with a context in which to situate these subjects; that context is engineering. An integrated, application-based approach to learning science may be helpful in cultivating an interest and an understanding of fields such as engineering that utilize scientific and mathematical knowledge (Anderson-Rowland et al., 2002).

A Constructivist Framework for Learning

Constructivist learning, which is a powerful form of learning, has been around for centuries but appears unfashionable in today's age of accountability and test scores (Funk, 2003). Constructivism, a learning theory supported by Jean Piaget, states that children construct knowledge about the world around them through active involvement in experiences that are meaningful for them which can be used to create an ideal learning environment (Piaget, 1970). If students are posed with the choice of learning via traditional modes such as lecture and worksheets or in a hands-on project based environment, students welcome the later of the two. In fact, teachers can better attend to their students' learning when the students are engaged in a hands-on learning experience. Research on how children learn has shown that young children's imaginations are more stimulated when they have the opportunity to work with actual materials (International Technology Education Association (2000). Larkin-Hein et al. (2002) state that the constructivist approach has been shown to enhance not only learning, but teaching as well.

According to Gil-Perez et al. (2002), a constructivist approach in science education provides active participation of students in the construction of knowledge and not the mere personal reconstruction of previously elaborated knowledge, provided by the teacher and/or textbook. Alesandrini & Larson (2002) report that the teachers' role in a constructivist environment is not to lecture or provide structured activities that guide students to mastery or some teacher-imposed goal. In addition, teachers act as facilitators who coach learners toward meaningful learning goals. With this is mind, it is important that science educators gain insights into teacher candidates' existing knowledge and perceptions of science teaching and learning to provide meaningful activities that prepare them to work effectively with students (Carnes, 2002).

Summary

Teaching and learning in the 21st century will be challenging to both educators and students alike. Subjects such as science and math are at the forefront of this educational reform. With Acts such as the No Child Left Behind of 2001 being signed into law, the education system will be held more accountable than ever for students' learning. The third Internal Mathematics and Science Survey (TIMSS) provides evidence that American students lag behind their international counterparts in both science and mathematics education (U.S. White House, 2001).

In the past, concerns about science education were motivated by the goal of insuring a pipeline of students moving toward careers in science and technology but we now see that technology infuses more and more aspects of our daily lives (U.S. White House, 2001). Furthermore, it was reported that students need a basic grounding in science and math to function in an increasingly complex world and to lead rewarding and fulfilling lives.

In order for teachers to become better prepared to handle accountability for their students' learning, teachers themselves need to become more accountable for how and what they are teaching in the classroom. Teacher preparation programs must provide preservice teachers with additional opportunities to learn about science and technology so that they can become more knowledgeable consumers of these subject areas. Preservice teachers also need to understand the importance of how these subject areas contribute and affect their own students' lives. Teacher preparation should include a wide range of activities including those that engage preservice teachers as active learners (National Research Council, 1996). Teachers must also be presented with a context in which to connect science and technology. Engineering can be viewed as an ideal forum for introducing and connecting these subjects.

Presenting engineering as a "context" to teach science and technology is essential. Educators are already so overloaded with the traditional curriculum that they are required to teach that they are often times reluctant to entertain the idea of teaching something new, even if it would benefit their students. There are simply not enough hours in the day to learn and teach something that teachers perceive as "new." Educators are often surprised that engineering concepts are already deeply embedded in the curriculum standards (Anderson-Rowland, et al., 2002) and that the national technology standards developed by the International Society for Technology in Education (ISTE) have strong connections to engineering (International Society for Technology in Education, 2000). In order to foster a positive environment in which to situate the connections of science and technology, some educators are now examining the learning theory of constructivism.

Classrooms that employ a constructivist framework for learning science, technology, and engineering, can provide authentic, hands on learning activities that can provide preservice teachers with opportunities to become active learners. The leaning theory of constructivism has shown promise in the areas of science and technology. Although there is controversy surrounding this learning theory, recent studies now provide information that students and teachers both benefit from learning in this environment. Students are more inclined to take on leadership roles in their learning experiences if they are allowed to create new knowledge through active participation while connecting it to preexisting knowledge.

Preparing Tomorrow's Teachers to Use Technology and the Technology Collaborative Project

The Department of Education developed a grant program called Preparing Tomorrow's Teachers to Use Technology (PT3) to address a growing challenge in modern education: nearly all elementary and secondary schools are now "wired" to the Internet, but many teachers still feel uncomfortable using technology in their classroom teaching (U.S. Department of Education, ¶1, 2004).

The College of Education at the Midwestern College researched for this study was awarded a $1.5 million dollar Pt3 grant. The Technology Collaborative (TechCO) project was initiated to use technology to facilitate renewal in both teacher education and K-12 schools (Thompson, Schmidt, & Davis, 2003). The researchers also state that two technology-rich cohort groups of preservice teachers were derived from this project and agreed to take all of their technology-rich education courses together for a period of three years beginning in their sophomore year of college. Additionally, nearly eighty percent of the participating cohort students elected to purchase an iBook laptop computer and those that elected not to purchase a computer had access to laptops provided by the program that were available on a check-out basis. The second cohort of participants, who consisted of 22 females, was researched for this study.

Statement of the Problem

Often times, preservice teachers graduating from teacher preparation programs are unprepared to successfully teach science and technology and willingly admit their discomforts and lack of knowledge in these subject areas.

There are few preservice teacher programs that employ engineering as a context to teach science and technology concepts. Few colleges in the United States capitalize on interdisciplinary collaborations stemming from the colleges of education and engineering that ultimately would help strengthen and connect preservice teachers' knowledge of science and technology.

The problem addressed in this study is the lack of research on preservice teacher education approaches to using engineering as a context for learning science and technology using a constructivist approach to learning.

Purpose of the Study

The purpose of this study is to describe the experiences and reactions of a cohort of education preservice teachers enrolled in an engineering course titled Toying With Technology. In addition, this study seeks to gain an in-depth understanding of how preservice teachers describe and report on learning in an engineering course that employs a constructivist approach to learning.

Research Design and Guiding Questions

The research described in this dissertation is a case study. Because I seek to gain an in-depth understanding of preservice teachers participation in an engineering course designed for education majors, I purposefully chose to use a qualitative methodology for this study. The following guiding questions will provide direction for this case study.

Research Questions

1. How do preservice teachers' perceptions develop while participating in a course featuring engineering principles?
2. As a result of this engineering course, how does the use of a constructivist approach in teaching and learning effect preservice teachers' perceptions of science and technology?
3. How do preservice teachers describe personal experiences with engineering based projects?
4. How do preservice teachers describe implementation of what they have learned about science, technology, and engineering?

Significance of the Study

Preparing students to become educated consumers of technology present in our ever-changing world had become an integral part of K-12 educational reform. Providing students with authentic hands-on opportunities to enhance their science and technology experiences in the classroom is integral to both students' personal and professional growth. Currently, there are few studies to support engineering as a context to teach science and technology in preservice teacher education programs. This study will provide an in-depth examination of how preservice teachers perceive learning in a constructivist based engineering course. Information obtained from this study will enable others to gain a better understanding of how engineering can be successfully used to integrate the content areas of science and technology. Furthermore, this study will address how preservice teachers can benefit from learning in a course incorporating a constructivist framework for learning science, technology, and engineering.

CHAPTER II

LITERATURE REVIEW

Today, more than ever, educators are being held accountable for student's learning. Educators face the expository undertaking of teaching students the skills necessary to flourish in an ever increasingly technological society (Schaefer, Sullivan, & Yowell, 2003). With high stake tests at the forefront of most learning objectives, educators often find themselves in a precarious position of how to incorporate and effectively manage the classroom curriculum that they are responsible for teaching. Educators are being held accountable for "teaching to the standards" and must show evidence of how their instruction meets or exceeds these curriculum standards.

While it is true that many students will not pursue careers in the field of engineering and technology, all students can directly benefit from possessing a basic understanding of how social, economic, and cultural systems are transformed by the integration of the two (Sullivan, Davis, deGrazia, & Carlson, 1999). Engineering, in the world as we know it today, is presented in almost every facet of our daily living; from operating our car on the way to work, to the roads we travel on to get to work to the building we walk into when we get to work. Students can directly benefit from knowing how engineering affects their daily lives so therefore, it is important to educate young people about engineering and more specifically how it connects with their daily life experiences.

Engineering is more than an appropriate context in which to situate the classroom subjects of science, technology, and mathematics. Engineering not only involves both applied science and mathematics standards but the concepts are deeply embedded in the standards as well (Anderson-Rowland et al, 2002). As the current science standards [relating to engineering] are presented, one difficulty is that they do not naturally relate to everyday life experiences (Anderson-Rowland, et al, 2002).

Convincing educators the value of incorporating engineering in the already existing curriculum has proven to be a troublesome obstacle. Teachers often shy away when faced with yet another daunting task of adding "one more thing" to their already full plate. The ability to convince an educator of the importance of engineering will initially vary based on the teacher's educational background (Rushton et al, 2002). Often times, educators are unaware that classroom curricula already support engineering concepts, and principles. According to Zachary, Sharp, & Adams (2000), engineering ideas already exist in the current mathematics and science curricula and would provide students with more options and a deeper understanding of these content areas.

However, elementary and secondary teachers must have practical knowledge of engineering in order to guide their students in the exploration of the ideas of engineering (Zachary, Sharp, & Adams, 2000) Even if educators are knowledgeable about engineering and aspire to enhance their science and math classrooms, they simply do not know where to fit the content material so that it aligns with both state and national standards (Anderson-Rowland et al, 2003).

The purpose of this chapter is to review literature related to this study. The following topics are included: Importance of Technology and Science Education, Engineering as a Context to Teach Science and Technology, Inadequate Science Education Preparation for

Preservice Teachers, Inadequate Technology Education Preparation for Preservice Teachers, and The Constructivist Approach to Learning & Teaching.

The focus on the Importance of Technology and Science Education was included in this chapter to show how both technology and science are vital components in K-12 education. Engineering as a Context to Teach Science and Technology was included to show how engineering could be used to situate both science and technology in order to facilitate optimal learning in the K-12 environment. Inadequate Science Education Preparation for Preservice Teachers and Inadequate Technology Education Preparation for Preservice Teachers were included to show evidence that higher education institutions are experiencing tribulations when preparing preservice teachers to adequately teach both science and technology in K-12 classrooms. Lastly, the Constructivist Approach to Learning and Teaching was included to provide support of how both learning and teaching by way of a constructivist approach could provide a viable solution for learning and teaching science, technology, and engineering.

Importance of Technology Education

When it comes to technology in education, you can create it, you can design it, you can produce it, you can legislate it, you can order it, you can restructure it, give it standards and outcomes for it. But the bottom line is that if it is going to happen, teachers are going to have to make it happen. ~ Jacqueline Goodloe, Washington, D.C. teacher

We are a nation that is increasingly dependent on technology but in spite of this, society is largely ignorant of the history and fundamental nature of the technology that sustains it (International Technology Education Association, 2000). Because of technology, people have been able to change the world and the promise of our future, which lies not only in technology but also in people's ability to use, manage, and understand it (International Technology Education Association, 1996). Moreover, while it is logical that the developers have advanced technological capabilities, it is absurd for the rest of the general public to be technologically illiterate. The report stresses that educational programs that are based on the universals of technology will provide students with the concepts and experiences necessary to develop an understanding and capability that they will need to function in a constantly changing technological world. Furthermore, school systems must establish and employ effective technological literacy efforts beginning in kindergarten and continuing each year through the high school years and beyond.

> Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education-meaning education in science, mathematics, and technology—should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital. America's future—its ability to create a truly just society, to sustain its economic vitality, and to remain secure in a world torn by hostilities—depends more than ever

> on the character and quality of the education that the nation provides for all of its children (Rutherford & Ahlgren, 1990, ¶ 2).

According to Rutherford & Ahlgren (1990), the majority of Americans are not science-literate. As stated by the authors, one only has to view international studies of educational performance to see that American students rank near the bottom in science. According to the American Association for the Advancement of Science (1990), and the National Research Council (1996), the importance of science is such that it should be introduced and taught at all levels of education. Additionally, every person should attain at least a minimal level of science literacy. There is more at stake than just the individual fulfillment one has in knowing about science, it is what the future holds in store for individual human beings, the nation, and the world which depends on the wisdom with which humans use technology and science (Rutherford & Ahlgren, 1990).

The importance of being scientifically literate resides in the following:

- Science, energetically pursued, can provide humanity with the knowledge of the biophysical environment and of social behavior needed to develop effective solutions to its global and local problems; without that knowledge, progress toward a safe world will be unnecessarily handicapped.
- By emphasizing and explaining the dependency of living things on each other and on the physical environment, science fosters the kind of intelligent respect for nature that should inform decisions on the uses of

technology; without that respect, we are in danger of recklessly destroying our life-support system.

- Scientific habits of mind can help people in every walk of life deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty; without the ability to think critically and independently, citizens are easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems (Rutherford & Ahlgren, 1990, ¶5-7).

Scientific literacy is not just a necessity for those going into scientific fields. Because our world is filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone because we all need to use scientific information to make choices that arise every day (National Research Council, 1996). Furthermore, scientific literacy is also of increasing importance in the workplace as more jobs demand advanced skills, requiring that individuals be able to learn, reason, think creatively, make decisions, and solve problems. It is unavoidable that we are entering a century that will be ever more dependent on both science and technology (Committee on Science and Mathematics Teacher Preparation, 2001).

The fields of science and technology are different yet similar because scientists and technologists often work together (Hacker & Barden, 1993). According to the National Research Council (1992) and the International Technology Education Association (2000), science is the study of the natural world whereas technology extends people's abilities to modify the natural world (International Technology Education Association, 1996).

> Science and technology are different, yet symbiotic. Technology is much more than applied science, and science is quite different from applied technology. When people use technology to alter the natural world, they make an impact on science. Science is dependent upon technology to develop, test, experiment, verify, and apply many of its natural laws, theories, and principles. Likewise technology is dependent upon science for its understanding of how the natural world is structured and how it functions (International Technology Education Association, 1996, p. 28).

The report continues to state that every technologically literate person should know some of the underlying basic science, mathematics, and engineering, concepts and the relationship they share with technology.

Society is experiencing a great technological momentum yet many teachers have not demonstrated an adoption of such advances and their instructional practices hardly reflect the integration of instructional technologies (Mitechem, Wells, & Wells, 2003). However, according to the authors, as teachers increase their awareness, understanding, and use of instructional technologies, they also increase their instructional procedures in regards to effective design. Moreover, student engagement in the classroom will also increase with the use of instructional technologies.

Importance of Science Education

To simply neglect science education is to deprive K-12 students of a basic education, handicap them for life, and deprive the nation of informed citizens and talented workers; a loss the nation can ill afford (American Association for the Advancement of Science, 1990).

Students are not being provided with optimal learning environments whereas science is concerned. According to the House Committee on Science Report (2001), several factors have been identified as contributing toward the national failure in science educator. These include: too many teachers teaching outside of their field, inadequate teacher preparation in the area of science, too few schools providing challenging science curricula and textbooks, and too few students taking advantage of advanced coursework.

In the past, there were major concerns about creating a pipeline of students moving toward careers in science and technology but now the focus has changed to viewing how technology infuses more and more of our daily life. Clearly, all students require a basic grounding in science and technology to function in an ever increasingly complex world in which to lead fulfilling lives (House Committee on Science Report, 2001). It has been shown while investigating children's thinking, preservice teachers often find out that they have gaps in their understanding of science (Yerrick, 2003, ¶ 3). Additionally, "Not all students have good experiences as science learners. In fact, many preservice elementary teachers are bothered by the fact that they had very few positive role models for teaching science." (Yerrick, 2003, ¶ 4).

While the above research presented a case and revealed the importance of science and technology literacy it is equally important to present the method that has shown promise in the delivery of both disciplines. Engineering, simply put, is the application of science and technology.

Engineering as a Context to Teach Science and Technology

In today's world, one can hardly navigate through daily activities without experiencing how engineering touches virtually every aspect of our existence. Therefore, engineering might be considered a very natural way of introducing K-12 students to aspects of science, mathematics and technology. Engineering has long been viewed as a branch of education that links principles of the physical world (science, math, and physics) to practical application (Committee on Engineering Education, 2004). Furthermore, engineering provides a practical context and purpose to science and mathematics understanding linking environmental sustainability and ethical and social responsibility to technology development.

Jackie Sullivan, co-director of the Integrated Teaching and Learning Program at Colorado College of Engineering states: "Kids are born engineers. They love hands-on learning, things that go boom, things that are slimy. Engineering is the perfect vehicle for making science and math relate to things in a kid's world" (Creighton, 2002, ¶ 38). According to Schaefer et al. (2003), K-12 educators are faced with the challenge of teaching students necessary skills to help them flourish in an ever increasingly technological society. Introducing engineering and technology curricula in the K-12 classroom as a vehicle for the integration of math and science can be accomplished with both comprehensive and interactive engineering lesson plans that incorporate a variety of hands-on activities (Schaefer et al., 2003). While it is true that many students will not pursue careers in the field of engineering and technology, all students can directly benefit from a basic understanding of how social, economic, and cultural systems are transformed by the integration of the two (Sullivan, Davis, deGrazia, & Carlson, 1999). Not only should students be introduced and allowed to experiment with engineering principles, they need to encounter this exposure at a young age. Educators agree that the elementary and middle school years is a crucial time period for perceptions of math and science (Sanoff, 2001). Moreover, if students are turned off to science and math when they are young, it is a very difficult task to change their negative opinions to positive ones in their high school years.

Students can effectively learn and integrate science and math concepts through applied engineering lessons that incorporate the use of hands-on activities (Schaefer et al., 2003). An appropriate engineering activity integrated into regular school curriculum can have two major results: first, teachers become able to see how engineering can compliment and tie together traditional classroom content (Rushton et al., 2002). When shown how engineering and computer science content can fit into existing lesson plans, teachers become more ready to use this material, which enriches students' educational experiences. The second major result of integrating engineering activities is that students are shown how engineering relates theoretical science, mathematics, social studies, and language arts materials being taught. The research continues to state that engineering often provides relevance to students, a factor often lost in traditional curriculum. This loss often leaves children, if not teachers without rationale for learning, retaining, or valuing the material. Ruston continues to state that practical, activity and constructivist based learning, used to reinforce or present relevance of important content and effectively influence increased information retention through application of learning, benefits student learning. Engineering can also provide an opportunity to encourage students to pursue education in math or science to be able to appreciate fully lessons given." (Rushton et al., 2002, p.25).

As stated by Rushton, et al. (2002), Massachusetts is the first state in the nation to require K-12 engineering education through the adoption of Science and

Technology/Engineering frameworks. Furthermore, Massachusetts is also the only state to have mandated engineering education with the most far-reaching and comprehensive programs in the United States. CU-Boulder's approach to engineering is presenting it to K-12 educators as a vehicle to address many of the science, technology, and math state educational standards to which they are required to teach (deGrazia, 2001). According to Rushton, et al. (2002) students benefit from viewing engineering as a problem solving method (e.g. a LEGO design project where students utilize the engineering design process). Furthermore, if students are posed with a project in the following way, students are better able to create a connection between real world problem solving and engineering.

> A team of scientists is on a small river island downstream from a dam that was just removed. The island is quickly eroding due to the greatly increased water flow that once was blocked by the dam. In a matter of days, the island will erode to the point that it will not be safe for the scientists to inhabit. The scientists have valuable data and equipment on the island that is too heavy for their boats to transport to the mainland. Design a method for transporting the scientists, their important research, and their equipment safely (Rushton et al., 2002, p. 5).

To non-engineers, the above problem is too overwhelming a task given no parameters, equipment lists, constraints, or solutions (Rushton et al., 2002). The authors continue to state that given that the project is assessed using an engineering design process of gathering research and brainstorming solutions, evaluating ideas, selecting appropriate materials, constructing a prototype, testing the design and redesigning, the task becomes much more manageable.

Engineering shows promise for situating both the areas of science and technology. Because engineering is the application of these two fields, students often work in a collaborative, problem solving, hands-on environment. Engineering could potentially provide an ideal context in which to present science using real world examples and problems but without having an adequate scientific background, many preservice teachers would obviously feel unprepared to introduce science even in this appropriate framework.

Insufficient Science Education Preparation for Elementary Preservice Teachers

The world looks so different after learning science. For example, trees are made of air, primarily. When they are burned, they go back to air, and in the flaming heat is released the flaming heat of the sun which was bound in to convert the air into tree. [A]nd in the ash is the small remnant of the part which did not come from air, that came from the solid earth, instead. These are beautiful things, and the content of science is wonderfully full of them. They are very inspiring, and they can be used to inspire others

-Richard Feynman

According to the National Research Council (1996), all students should be provided with the opportunity to become scientifically literature. The Standards regard science literacy as an understanding of science, which makes it possible for everyone to share in the richness and excitement of comprehending the natural world. Furthermore, possessing a sound ground in science strengthens many of the skills that people use on a daily basis, like creatively solving problems, thinking critically, working cooperatively in teams, utilizing technology effectively, and valuing life-long learning.

Becoming an effective science teacher is a process that starts in the student's preservice educational experiences where they actively engage in science and gain some experience in teaching and continues right into their professional careers (National Research Council (1996). Additionally, prospective teachers of science education acquire much of their formal science knowledge from coursework in universities and colleges. Therefore, better science teaching is grounded, first of all, in improving the quality of teacher preparation (Boston, 2000). As stated by Plourde & Alawiye (2003), there is a concern that elementary science education is lacking in areas that will equip preservice teachers to effectively teach science to elementary students once they arrive in their future classrooms.

Elementary preservice teachers often declare their love of children as a motivating factor in their career choice (Howes, 2002). The author also argues that the important aspect of learning to teach is also learning how to recognize that children are intellectual beings and that the main object of the science teacher is to actively engage children in thinking about particular things (e.g., natural phenomena such as growth and light) and particular ways of thinking (e.g., observing, predicting, hypothesizing, testing, and explaining). As stated by Feiman-Nemser & Remillary (1996) (in Southerland and Gess-Newsome, 1998):

> ...learning to teach does not begin with entrance into teacher education programs. Instead, teacher candidates bring into a program a lifetime of historically and culturally situated knowledge of what it means to know, to learn, and to teach. That knowledge becomes a tool that influences how prospective teachers interpret their educational experiences. Thus, as science

educators, we must understand the images of knowledge, teaching, and learning that our students bring to our courses (p. 146).

Like many people, elementary teachers may find science disconnected from everyday life and thinking (Cobern & Loving, 2002). Additionally, teachers may wonder if science is merely a school subject that is unimportant in everyday life and a subject that conflicts with important personal believes related to cultural knowledge, religion or art. The authors stress that elementary teachers who may feel this disconnection with science would at best approach science instruction as something one does if school authorities demand it.

Most schools have expected elementary school teachers to be generalists (National Research Council, 2001). However, according to the National Research Council's report, teachers need a comprehensive knowledge and understanding of science and mathematics to teach these subjects effectively at any grade. Furthermore, colleges programs that prepare preservice teachers often emphasize and reinforce the notion of elementary teachers as non-specialists. Others have suggested that teachers of all grade levels must comprehensively understand subject matter that they teach and use this knowledge to teach what is appropriate to students at varying grade levels (pedagogical content knowledge) if they are to be effective classroom teachers (Shulman, 1987). According to Yerrick (2002), one drawback of teacher education programs offering only one science methods course is that science is not a generic process. Learning to teach curricular constraints of the elementary schools with which we collaborate biology is different from the process of learning to teach physics but, because of a factor of time, we often must teach only one science topic. This severely limits the exposure of preservice teachers to a variety of strategies for teaching biological, physical, and chemical sciences. This can present a challenge because inquiry-based teaching methods for biology are not equivalent to those used in physics or chemistry (Yerrick, 2002).

In teacher preparation colleges that require prospective elementary school teachers to major in a discipline other than education, few preservice teachers select majors in science or mathematics (National Research Council, 2001). Traditional views of teaching such as the notion that "You do not need science to be an elementary teacher" usually relegates prospective elementary teachers to more conventional, lecture format science courses (Levitt, 2001). Moreover, elementary teachers may be convinced of the value of hands-on activities and the use of cooperative learning from their elementary science methods courses and from other general pedagogical workshops, but they are not able to develop science content from these activities. Those preparing to become elementary school teachers may view science as confusing or incomprehensible because of the discomfort caused by the cognitive dissonance that results from perceiving scientific phenomena that do not support already held alternative conceptions of science (Schoon & Boon, 1998). Additionally, preservice teachers need to observe their college instructors model methods of teaching science to help them develop good, sound teaching practices.

Arguments that support the need for science education in elementary schools are based on the desire to develop the knowledge, reasoning, and problem-solving skills required for a rapidly changing technological society (American Association for the Advancement of Science, 1993; National Science Teachers Association, 1996). According to the 2000 National Survey of Science and Mathematics Education: Status of Elementary School Science Teaching, national standards call for the introduction of science content to all students beginning in the early elementary grades. A survey was taken of 5,728 science and mathematics teachers across the United States. Less than one third of these elementary teachers felt well qualified to teach each of the science disciplines. Furthermore elementary science schoolteachers were lacking in content preparation, especially in the physical sciences. Relatively few teachers in K-5 education report feeling well qualified to teach specific science disciplines. According to Kaufman (1992), science teachers have a lot of anxiety about science because they feel they are not well prepared. Rigden (1993) further states that teachers are a product of a system that has not served them well and lack sufficient knowledge in terms of both content and methodology which is an extensive, comprehensive preparation in terms of what science is and how to teach it. Additionally, poorly prepared teachers operate at their very worst when instruction is driven by merely a textbook. Besides equipping preservice teachers with tools that may not work, required education courses do even greater harm when required courses in pedagogy displace courses in biology, chemistry or calculus (Kanstoroom, 1999).

According to Abell & Roth (1992) and Atwater, Gardner, & Knight (1991), many elementary schools do not see their roles as providing time and leadership for practical, reflective classroom experiences for student teachers so that they have considerable opportunities to develop their capabilities within the context of their student teaching experiences. Additionally, teachers already in the teaching force do not apply best practices when teaching science and essentially do not exhibit adequate science teaching skills. Because elementary teachers feel they may not, but should, have all of the right answers when a student poses a questions, they avoid situations where these kind of questions are asked, i.e., they avoid teaching science (Levitt, 2001). Additionally, teachers may rely solely on the information that is provided in a textbook for teaching science. The author stresses that in either case, the teacher's beliefs about science and about his or her role in elementary science influence decisions about the teaching of science. Furthermore, numerous elementary teachers believe that they need sophisticated equipment in order to teach science and that science concepts are just too advanced for elementary students to understand often overlook the science occurring in children's everyday lives.

Few elementary teachers even possess a rudimentary education in science (American Association for the Advancement of Science, 1990). This would easily explain why many elementary school teachers are often reluctant, even afraid, to teach science believing that they are deficient in both procedural expertise and content knowledge (Bencze & Hodson, 1998). Elementary teachers also report that they are not well prepared for teaching the subject of science (Appleton, 1995). As stated by Harlen and Holroyd (1997), teachers that indicate that they are ill prepared to teach science often resort to one or more of the following coping strategies: teaching minimal science, focusing on areas of science in which their confidence level is the highest, relying on textbooks, kits and worksheets, avoiding use of an apparatus that could malfunction, avoiding all but the most simplistic hands-on work, emphasizing an expository teaching method, and using and relying on outside experts frequently (Harlen & Holroyd, 1997).

It is completely absurd to expect classroom teachers to create the necessary experiences for students to develop abilities in themselves if they have not had similar experiences (Bencze & Hodson, 1998). Furthermore, It is unrealistic to expect these students to possess confidence in their own judgment, skills, and knowledge if their own teachers have been socialized into a sense of blind acceptance of the views and decisions of others.

Suggestions have been presented to aid in the reform of teacher preparation programs. The Committee on Science and Mathematics Teacher Preparation are certain that the recruitment of high quality teachers in science and technology is truly a national need and must become a national priority (National Research Council, 2001). In addition, introductory courses at the collegiate level should be structured in a way that help all students gain a more profound understanding of the role and relationship of the sciences to other disciplines, to students' lives, and to helping students formulate informed decisions about issues in which science and technology play integral roles.

Just as research has suggested that preservice teachers are unprepared to teach science, research also suggests that students are just as unprepared to teach using technology.

Inadequate Technology Education Preparation for Preservice Teachers

According to the International Technology Education Association (2000), we are a nation increasingly dependent on technology. Yet, in spite of this dependence, U.S. society is largely ignorant of the history and fundamental nature of the technology that sustains it. The result is a public that is disengaged from the decisions that are helping shape its technological future. In a country founded on democratic principles, this is a dangerous situation (International Technology Education Association, 2000).

Today, every human activity is reliant on various systems, machines, and tools from providing shelter, growing food, to communication, entertainment, and healthcare (International Technology Education Association, 2000). Additionally, there are machines like the tractor that make more efficient activities that humans have done for hundreds of thousands of years and other such as the airplane or the Internet that make things possible that humans have never been able to do before. Technology consists of a collection of devices, capabilities, and the knowledge that accompanies. (International Technology Education Association, 2000).

The past three decades has shown an increase in the use of technology in many sectors of society (Hare, Howard, & Pope, 2002). The authors continue to state that integration of technology into teaching methods and practices of elementary school teachers has not been fully implemented. According to Gerald & Williams (1998), by the year 2008 it is projected that schools will hire approximately two million new K-12 teachers. This sudden influx of new teachers places a burden on colleges and universities to address the technological needs of these preservice teachers (Hare, Howard, & Pope, 2002). However, technology is not fundamental to the preservice teacher's preparation program at most colleges of education (Office of Technology Assessment, 1995). This report continues by stating that most new teachers graduate from teacher preparation institutions with limited knowledge of how technology can be used in their future classrooms or professional practice. In addition, most technology instruction is teaching about technology as a separate subject and is not teaching using technology across the curriculum. The majority of teacher education faculty do not model technology to accomplish objectives in the courses that they teach and seldom are students actually asked to create lessons within these courses that utilize technology or technological tools (Office of Technology Assessment, 1995).

According to Brush and Evans (2002), educational technology can:

> Allow learning to occur in ways not possible otherwise; be a means for improving learning in all subjects; expand students' creative abilities; promote students' taking responsibility for their own learning; impact at-risk student populations positively; promote students' interaction with a larger community (e.g., discussions directly with experts, with other students working on the same or similar projects, etc); give students experience with modern workplace tools (p. 2296).

Colleges of education face a predicament in preparing preservice teachers for the future (Gillingham & Topper, 1999). Moreover, technology is advancing into classroom cultures but faculty in teacher preparation programs are unsure of what to teach to preservice teachers or how to use technology in their own classroom instruction. The single course approach to teaching preservice teachers about educational technology, although not the not the only model, appears to be the dominant model for technology preparation (Hargrave & Hsu, 2000). Instruction in a single technology course often concentrates on learning about computers and fails to prepare future teachers on technology use as both an effective teaching and learning tool or to demonstrate how specific technology applications can be used in specific teaching disciplines (Office of Technology Assessment, 1995). A study conducted by Strudler, McKinney, Jones, & Quinn (1999), found that beginning teachers are not being adequately prepared to teach with computers and related technologies. Furthermore, while improvement in the amount and quality of course work in educational computing provides one way of addressing these needs, many have recognized that participating in only one required course is inadequate in preparing teachers to effectively use technology. And, often the current focus of instructional technology for preservice teacher preparation is based on computer technology opposed to educational media or instructional design topics (Hargrave & Hsu, 2000).

It is crucial that preservice teachers enter their respective fields equipped with educational technology skills and experience (Evans & Brush, 2002). Additionally, teacher education programs, which are responsible for preparing preservice teachers to integrate technology, must work collaboratively with the school systems to ensure that student teaching experiences occur in learning environments that support the integration of technology. Telling students about what is possible with technology is not enough; they must actually observe technology used by their instructors, observe use of technological tools in classrooms and have an opportunity to practice teaching with technology if they are to use these tools effectively in their own teaching (Office of Technology Assessment, 1995). Furthermore, teachers teach as they have been taught so it is also vitally important that effective teaching, which includes teaching with technology, is modeled not only in teacher preparation program courses, but other parts of the university preparation of prospective teachers (Office of Technology Assessment, 1995).

In a survey commissioned by the Office of Technology Assessment (1995), half of recent graduates surveyed reported being prepared to teach with drill and practice, tutorials, writing and publishing centers, and games, less than one in 10 felt that they could use formats such as multimedia packages, electronic presentations, problem-solving software, or collaborations over networks. Additionally, approximately 25% of teacher education graduates reported being minimally prepared and the remainder rated themselves as being prepared at varying levels. According to Topp (1996), recent graduates surveyed claim to be interested in utilizing technology and believe that computer related technologies are important in K-12 education. Moreover, the majority of these respondents reported their proficiency of technology as low and reported that they used computers infrequently.

A study conducted by the National Center for Education Statistics (2000) found that educators stated that technology was important to the educational system's reform but only 20% of these teachers believed that they were actually prepared to integrate technology into their classroom instructional practices. Findings from a two-year evaluation study of a preservice teacher technology infusion project reported that preservice teachers began technology courses with naive and narrow views of technology and how it might be applied in the classroom (Beyerbach, Walsh, & Vannatta, 2001). Comments such as, "I thought the teacher would assign a paper and the students would type it," and "I only used technology for word processing and e-mail" (p.121) were very characteristic statements.

As Gros (2002) pointed out, one of the most important issues facing education today is that most instructive approaches do not readily correspond to the needs of today's children and the society in which they live. Additionally, "the separation of knowledge, the communication of information, the one-directional teacher-student model, and the idea of knowledge as something static are set against a much more dynamic and complex vision of knowledge" (p. 326). The constructivist theory has led to different approaches and uses of technology that have provided significant advances.

The Constructivist Approach to Learning & Teaching

Educational technologists have often stated that an effective way to integrate technology into the teaching and learning process is to follow a constructivist model.

Although teachers may have technical skills, they may not understand how constructivism translates into meaningful classroom practice (Sprague & Dede, 1999).

Jerome Bruner proposed that learning is an active process where a learner constructs concepts or ideas based on his or her own past knowledge (Shelly, Cashman, Gunter, & Gunter, 2004). As stated by Brooks & Brooks (1993), constructivism is not a theory about teaching but rather it is a theory about knowledge and learning. Constructivism is about knowledge and learning and describing both what "knowing" is and how one "comes to know." (Fosnot, 1996)

> The key idea that sets constructivism apart from other theories of cognition was derived by Jean Piaget approximately 60 years ago (Glaerfield, 1996). Additionally, "it was the idea that what we call knowledge does not and cannot have the purpose of producing representations of an independent reality, but instead has an adaptive function." (p.3) Glaerfield states that in Piaget's constructivist theory one simply cannot draw conclusions about the character of the real world from an organism's adaptedness or the viability of schemes or actions. Additionally, in Piaget's view, what we feel, hear, see-that is, our sensory world, is the direct result of our own perceptual activities and therefore specific to our own ways of perceiving and conceiving. "Knowledge, for him, arises from actions and the agent's reflection on them" (Glaerfield, 1996, p.3). According to Ackerman (1996), Piaget has taught us that knowledge is not a commodity to be transmitted and information is not something that is to be delivered at one end, encoded, stored and reapplied at the

other end. Ackerman states "knowledge is experience, in the sense that it is actively constructed and reconstructed through direct interaction with the environment. This idea is similar, in many ways, to the ideas expressed by various "situated cognition" scholars: To know is to relate" (Ackerman, 1996, p. 26).

Constructivists emphasize the direct relationship between learning and the degree to which the environment provides a rich source of engaging experiences (Rieber, 1993). Additionally, proponents of constructivism emphasize the quality of knowledge rather than the quantity. The author stresses that learning is not necessarily viewed as the acquisition of knowledge but rather as the constant reconstruction of what is already known. Furthermore, individuals do not simply add information they either revise existing mental structures to accept any new information or formulate new structures based on old ones when an existing structure is no longer sufficient.

Learning in a Constructivist Environment

Learning from the constructivist perspective is understood as a self-regulated process of resolving inner cognitive conflicts that often become apparent through concrete experience, collaborative discourse, and reflection." (Brooks & Brooks, 1993) The constructivist view of learning suggests an approach to teaching that provides learners with the opportunity for concrete, contextually meaningful experiences through which they can derive their own models, strategies, and concepts (Fosnot, 1996). Learners gain knowledge through discovery learning and are treated "a candle to be lighted" (Rieber, 1993, p. 207). Supporters of constructivism advocate discovery learning based on inductive strategies where learners must induce and interpret (construct) principles from a set of specific examples or occurrences of the principles (Brunner, 1966 as stated by Rieber, 1993).

Wilson (1996) describes a constructivist learning environment as a place where learners often work together and support each other using a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities. The author continues to state that constructivism emphasizes learning environments as opposed to instructional environments to encourage a more flexible idea of learning, one which focuses on meaningful, authentic activities that assist the learner in constructing understandings and developing skills that are relevant to problem solving.

Constructivist learners are active learners that are actively engaged within the learning process (Shelly, Cashman, Gunter, & Gunter, 2004 & Sprague & Dede, 1999). Students share ideas, ask questions, discuss concepts and revise their ideas and misconceptions of ideas (Sprague & Dede, 1999). These types of collaborative environments encourage the knowledge construction needed for more lasting learning (Jonassen, 1996). Fox (2001) describes constructivism as a metaphor for learning, likening the acquisition of knowledge to a process of building or construction. Additionally, Fox states that human beings acquire knowledge of their environments by acting upon the world around them as well as being acted upon. Furthermore, we do things and have things done to us; we act and we react, and clearly we capable of learning from both experiences.

If there are commonalities amongst constructivists of differing persuasions, it presumably lies in the idea that the development of understanding requires active engagement on the part of the learner (Jenkins, 2000). Fox states the following claims define the constructivist views of learning: learning is an active process, knowledge is constructed, rather than innate, or passively absorbed, knowledge is invented not discovered, all knowledge is personal and idiosyncratic, all knowledge is socially constructed, learning is essentially a process of making sense of the world, effective learning requires meaningful, open-ended, challenging problems for the learner solved. As stated by Jenkins (2000), knowledge cannot be 'given' or handed over and received in the same way that a parent might offer a child a toy, tool, or book. When characterized in this way, constructivism has a long ancestry and accommodates considerable flexibility.

> Current studies of how children learn science are often framed by a constructivist view of science teaching and learning. Central to this perspective is the premise that a learner constructs meaning from new information and events as a result of an interaction between that individuals prior knowledge and experiences and her or his current observations. The capacity to recognize that children do *actively construct* their knowledge and beliefs may lead a teacher to consider the possible interpretations that the learner might make of science classroom events. (Aguirre et al., 1990, p. 381).

Teaching in a Constructivist Environment

Educators are becoming increasingly more aware that learning must move from a more traditional approach where learning is viewed as passively absorbing knowledge to the idea that knowledge is constructed by the learner and made meaningful through life experiences (Zachary, Sharp, & Adams, 2000). As teachers, we are taught to believe that optimal learning occurs in quiet and orderly settings and activities that include students taking an active role by sharing information with each other make for noisy classrooms (Sprague & Dede, 1999). However, according to Carr, Jonassen, Litzinger, & Maria (1998), these types of activities are often times more motivating and interesting to students because the activities tend to be more learner-focused and authentic which encourages critical thinking and creates lasting, transferable, and useful knowledge. As stated by Jonassen (1991), many educators have applied constructivism toward the development of learning environments. From these learning environments, Jonassen has isolated the following design principles:

> Create real-world environments that employ the context in which leaning is relevant, focus on realistic approaches to solving real-world problems, the instructor is a coach and an analyzer of the strategies used to solve these problems, stress conceptual interrelatedness, providing multiple representations or perspectives on the content, instructional goals and objectives should be negotiated and not imposed, evaluation should serve as a self-analysis tool, provide tools and environments that help learners interpret the multiple perspectives of the world, learning should be internally controlled and mediated by the learner (Jonassen, 1991, p. 11-12).

Activities should also be authentic, problem-based activities rather than drill and practice, which allow students to develop a deeper understanding of the knowledge domain (Sprauge & Dede, 1999). Additionally, constructivist teachers encourage student inquiry by asking thoughtful, open-ended questions and encourage students to ask questions not only of the teacher, but to each other as well. As stated by Fosnot (1996), just as young learners construct knowledge, teachers do as well.

> Teacher education programs based on a constructivist view of learning need to do more than offer a constructivist perspective in a course or two. Teachers' beliefs need to be illuminated, discussed, and challenged. Teachers need to be engaged in learning experiences that confront traditional beliefs, in experiences where they can study children and their meaning-making, and in field experiences where they can experiment collaboratively (Fostnot, 1996, p. 216)

As educators become more aware of constructivist approaches to both learning and teaching, a deeper understanding of how constuctionism, which is built upon Jean Piaget's constructivist theory, should also be examined.

Constructionism

The difference between Piaget's constructivism and Papert's constructionism is that constructivism offers a window into what children are interested in and able to achieve at varying stages in their development (Ackermann, 2002). Moreover, the theory illustrates how children's ways of thinking and doing evolve over time, and under which circumstance children are more likely to actually let go-or hold onto- their currently held views. Furthermore children have very good reasons not to abandon their views just because someone else informs them that they are wrong. The researcher contends that constructionism focuses on the art of learning, or learning how to learn with special emphasis placed on creating artifacts. Papert is interested in how learners engage in conversations about artifacts and ultimately how these conversations boost self-directed learning, which facilitates the construction of new knowledge. In simplest terms, constructionism evokes the idea of learning-by-making (Papert, 1991).

> Constructionism the N word as opposed to the V word-shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity (Papert, 1991, pg. 1).

Constructionism is considered both a theory of learning and a strategy for education (Kafai & Resnick, 1996). Additionally, children do not acquire ideas, they construct them because learners are more apt to construct new ideas when they are actively engaged in creating some type of external artifact-be it a robot, a sand castle, a poem, or a computer program. The researchers state that "constructionism involves two intertwined types of construction: the construction of knowledge in the context of building personally meaningful artifacts" (Kafai & Resnick, 1996, pg. 1).

Constructionism emphasizes the notion that through the construction of shared outcomes and artifacts, a subject engages in a developmental cycle in the social setting (Shaw, 1996). Additionally, social constructionism broadens the constructivist view by explicitly including as constructions the social activities and social relations that become shared outcomes and artifacts at work in the developmental cycle. The researcher states that the social setting in social constructionism is an evolving construction and when members of a social setting develop externally and shared social constructs, they actively engage the setting in a cycle of development that is critical to determining the setting's ultimate form. "Social constructionism focuses on the developmental ramifications inherent in the social nature of certain constructions" (Shaw, 1996, pg. 178).

Summary

As we enter the 21st century, the importance of science and technology are becoming increasing evident. According to the National Research Council (1996), our world is filled with products of scientific inquiry and scientific literacy has become a necessity for everyone. Furthermore, jobs are demanding more advanced skills that require people to be able to learn, reason, think creatively, make decisions, and solve problems.

K-12 students must to be able to function in an ever-changing technological world so authentic experiences to learn both science and technology must be provided for these children. According to Bently, Ebert, & Ebert (2000), children can develop a richer and more realistic conception of the nature of science if they are guided through their work with each other, conducting investigations and constructing knowledge in a constructivist-based classroom. A constructivist view of science states that classroom activities and investigations should be less like cookbook recipes and more like open-ended investigations of real scientific work where children use tool as scientists do. (Bently, Ebert,& Ebert, 2000). Engineering can be used as a practical context to teach science and technology.

According to Anderson-Rowland et al (2002) engineering involves the applied mathematics and sciences and usually goes unrecognized as a potential vehicle for addressing the content standards of math, science, and technology. Moreover, engineering provides real-world connections to curriculum standards concepts, which are deeply embedded in the standards. Anderson-Rowland et al also content that teaching can become more interesting and enriched by including engineering in science classes.

CHAPTER III

METHODS

"We were able to figure out how to make the car turn at a 90-degree angle. At first we had problems because (the car) was turning too far, at almost a 120-degree angle. We played around with the computer and the car to make it turn and we succeeded! We also made the car follow the tracks. It was difficult to picture it in our heads and what happened was it was different then what we thought we had told the computer to do. We needed to figure out which way the car was going to go and get it into the "garage" but when you're doing it in your head, it sometimes gets confusing. By trial and error we finally figured out how to make the car go the way we wanted. ………… I have never programmed on a computer before and this was my first time experience with something like this. Just to be able to say I figured out some type of engineering is great for me. It's very exciting to say I have computer programmed and many people are interested with that. (Brooklyn, Journal Entry 2/05/02)

Introduction

The purpose of this descriptive case study is to describe the qualitative research methods used to investigate how a cohort of education preservice teachers report on performing, learning, and participating in an engineering course that uses a constructivist approach to learning. This chapter provides details about the preservice teachers and explanations of how data were collected and analyzed and more specifically, the data coding protocol.

Qualitative Research

You know my method. It is founded upon the observation of trifles.

-Sherlock Holmes in the Boscombe Valley Mystery by A. ConanDoyle

> (Qualitative research) is an effort to understand situations in their uniqueness as part of a particular context and the interactions there. This understanding is an end in itself, so that it is not attempting to predict what may happen in the future necessarily, but to understand the nature of that setting-what it means for preservice teachers to be in that setting, what their lives are like, what's going on for them, what their meanings are, what the world looks like in that particular setting-and in the analysis to be able to communicate that faithfully to others who are interested in that setting...The analysis strives for depth of understanding. (Patton, 1985, p.1)

As qualitative research is gaining recognition in the education discipline, more literature is appearing on the different methodological approaches to conducting qualitative research. Merriam (2001) explains that qualitative research is an umbrella concept that covers several different forms of inquiry that help researchers to understand and explain the social phenomena with the least amount of disruption to the natural setting as possible. She further states that other authors or researchers often refer to qualitative research in interchangeable terms such as naturalistic inquiry, field study, interpretive research, inductive research, ethnography, participant observation, and case study. Qualitative research can be fairly time consuming for the researcher and is often used in smaller-scale case study based research that is concerned with a more subjective experience and social meaning (Burgess, 1985). However, "the key philosophical assumption upon which all types of qualitative research are based is the view that reality is constructed by individuals interacting with their social worlds. Qualitative researchers are interested in understanding the meaning people have constructed, that is, how they make sense of their world and the experiences they have in the world" (Merriam, 2001, p.6).

Characteristics of all forms of qualitative research includes the following: the researcher is the primary instrument for the collection of data and analysis, researchers are interested in the meaning that people have constructed of the world in which they live, most often it requires fieldwork, employs an inductive research strategy, and the final product of qualitative research is richly descriptive (Merriam, 2001). Merriam continues by stating that the above mentioned are the most common characteristics to qualitative however, one should not forget to address the not so common characteristics of qualitative research. The study is designed to be emergent and flexible in nature, samples are non-random but are purposeful and small, and the investigator involved in qualitative research must spend a great deal of time in the *natural* setting of the study in intense and personal contact with the preservice teachers. Just as there are common characteristics of a qualitative research study, there are also some common techniques involved in gathering data.

Burgess (1985) describes qualitative techniques as involving more open-ended responses, questions that are based upon very informal or loosely structured interviews, observations or journals. Qualitative research lends itself to studies that are not intended to be generalizable but rather to be descriptive and for the purpose of going in depth with a situation or person to gain a better understanding of this situation or person. But choosing to conduct qualitative research is a personal choice and journey, one that cannot be undertaken by just anyone. Careful consideration must be taken so that the researcher can decide if their study lends itself to a qualitative study and if they can do the field of qualitative research justice by their study. Researchers need to remember that qualitative research, which focuses on meaning in relation to context, requires a data collection instrument that is sensitive to underlying meanings when not only gathering but also interpreting data (Merriam, 2001). One research method employed by qualitative researchers is case study research.

Case Study Design

A case study, used in qualitative research is employed to gain a more in-depth understanding of the situation and meaning for those that are involved (Merriam, 2001). The case study, like many other research methods, is a way of investigating an empirical topic by following a set of predetermined procedures (Yin, 1994). It is research that does not lend itself to sampling because the researcher does not study a specific case in order to understand other cases (Stake, 1995). Because case studies are on their way to becoming more predominant and accepted in the field of education, they are often framed with the concepts, theories and models from the fields of anthropology, sociology, psychology, educational psychology and history that have used case study research for much longer (Merriam, 2001). Platt (1992) discovered that the majority of textbooks that report on research methods published during the years of 1970-1979 even failed to mention case studies at all. However, it was not until the mid 1980s that case studies started appearing again.

Wilson & Gudmundsdottir (1987) assert that case study research is becoming increasingly significant; especially as qualitative research methods are finding a firmer foothold within the educational research community. And, like the doctors, lawyers and anthropologists before them, educational researchers are finding that the notion of case study research is helpful in coming to terms with complex phenomena. After all, "the case is a specific, complex, functioning thing" (Stake, 1995 p.2). Case studies can be classified by the following: descriptive case study, interpretive case study, and the evaluative case study (Merriam, 2001). But regardless of the type of case study, investigators must exercise great care in the designing and implementation of case studies in order to overcome the traditional criticisms of this type of method (Yin, 1994). Merriam (2001) provides an overarching idea of the case study method:

> Case studies can be defined in terms of the process of conducting the inquiry (that is, case study research), the bounded system or unit of analysis selected for study (that is, the case), or the product, the end report of a case investigation. Further, qualitative case studies are particularistic, descriptive, and heuristic. Because a case study has these attributes, a researcher might choose this approach to illuminate a phenomenon. Case studies can also be understood in terms of their disciplinary framework, which commonly draws from anthropology, history, psychology, and sociology. Whether the studies

> describe, interpret, or evaluate a phenomenon or build theory are issues also considered. (Merriam, 2001 p. 43)

My research design entailed a case study. According to Stake (1995), a case study is the study of the complexity and particularity of a single case and coming to understand its activity within important circumstances. "To live with ambiguity, to challenge certainty, to creatively encounter, is to arrive, eventually, at 'seeing' anew" (Simons, 1996 p. 238). Simons also notes, case study research is unique and has a capacity for understanding different levels of complexity in particular contexts.

A case study approach was chosen for the following reasons:

- this study was exploratory in nature
- this study fits more closely with the sample and type of data that I, the researcher, planned on gathering
- to gain a more in-depth understanding of the cohort and their interactions with the Toying With Technology course
- as the researcher, I was able to get close to the preservice teachers and have direct observations in the preservice teachers natural setting

Case studies provide researchers with opportunities such as access, or going places where most of us would not go, seeing through the eyes of the researchers or seeing things we otherwise might not have seen (Peshkin, 1990). Traditionally, a case study follows a single entity or phenomenon over a given period of time, while using a variety of procedures to collect data over this specified time period (Creswell, 1994), and when a unique or extreme case is presented it is appropriate to study a single case in depth (Yin, 1989). The cohort of education majors is considered a unique case in the College of Education at this institution. The preservice teachers participating in this cohort were required to enroll in an engineering course that is not typically required of preservice teachers in the College of Education.

Descriptive Case Study

A descriptive case study design was employed for this research study. "A descriptive case study in education is one that presents a detailed account of the phenomenon under study-a historical case study that chronicles a sequence of events, for example." (Merriam, 2001, pg. 38) Moreover, descriptive case studies are useful in presenting information about areas of education where little research has been conducted and often times innovative programs and practices are the focus.

According to Marshall & Rossman (1999), many qualitative studies are both descriptive and exploratory in nature that build rich descriptions of complex circumstances that are virtually unexplored in the literature. Furthermore, descriptive case studies document and describe the phenomenon of interest. General research questions associated with this approach include; "What are the salient actions, events, beliefs, attitudes, social structure, and processes occurring in this phenomenon?" (Marshall & Rossman, 1999, p. 33). This descriptive case study intends to examine and explore the following four research questions, which aids in the description of the phenomena of the preservice teachers' interactions in the Toying With Technology course.

1. How do preservice teachers' perceptions develop while participating in a course featuring engineering principles?
2. As a result of this engineering course, how does the use of a constructivist approach in teaching and learning effect preservice teachers' perceptions of science and technology?
3. How do preservice teachers describe personal experiences with engineering based projects?
4. How do preservice teachers describe implementation of what they have learned about science, technology, and engineering?

Role of the Researcher

> Qualitative researchers stress the socially constructed nature of reality, the intimate relationship between the researcher and what is studied, and the situational constraints that shape inquiry. They seek answers to questions that stress how social experience is created and given meaning (Denzin & Lincoln, 1994, p. 4).

During this study, I am the primary data collection instrument; therefore it is important for me to describe my personal connection with the Toying With Technology course to be able to acknowledge and express possible biases. For the past three years, I have taught the Toying With Technology course in the roles of both a primary instructor and as a co-instructor, sharing teaching responsibilities with a professor in the College of Engineering. As a graduate student in the College of Education, I was provided with a teaching assistantship that allowed me the opportunity to teach the Toying With Technology course. Early in the assistantship, I was confronted with learning new engineering content and material. As I reflect on this experience, I empathize with the struggles experienced by the preservice teachers as they approached learning about science and technology in the context of engineering.

Each semester that I was responsible for teaching Toying With Technology, I tailored the course material to meet the emergent needs of the preservice teachers. I attempted to directly relate the curriculum of the course to be useful for the preservice teachers when they entered the world of teaching and were responsible for their own classrooms. As a result of observing the preservice teachers throughout the semesters, I became increasingly interested in their perceptions and experiences. I possessed a strong desire to learn more about how education majors learned in a constructivist environment. I sought to discover if preservice teachers actually learned more about the field of engineering, enough to be able to recognize the importance and to be able to transfer this knowledge into their future teaching experiences. I questioned if preservice teachers valued learning about engineering and recognized a direct correlation to the curriculum that the preservice teachers would be faced with teaching when they entered their own classrooms in several years. The Toying With Technology course was important and highly regarded by me because I was allowed a great deal of latitude within the course to be able to make changes in curriculum and course content as needed. I was also valued and highly regarded as the resident K-12 "expert" by the engineering professor who co-taught this course. Positive teaching experiences in the Toying With Technology course initiated the process of carefully crafting a case study that would allow me to investigate and research preservice teachers actively participating in an engineering course that used a used a constructivist framework for learning science, technology, and engineering. After deciding and drawing upon a qualitative approach, the research venture began.

As a researcher of a case study, my role in the research process consisted of a participant observer and primary instructor of the Toying With Technology course. As stated by Creswell (1994), the researcher is considered a major instrument in the study. In Robert Burgess's Field of Methods In the Study of Education (1985), Andrew Pollard describes a researcher experience that will closely parallel that of my role in this research study.

> The most important method that I intended to use was that of participant observation. Obviously I was a full participant because of my teaching position and a key question therefore concerned with the degree and manner in which I could also fulfill the role of "observer". I was conscious of the fact that I had to maintain both roles in, as Hughes (1952) put it, 'an unending dialectic'. In particular, I had to be careful to avoid 'going native'. The phrase 'going native' essentially describes a state of mind in which, through a very close and emphatic identification with the subjects of the research, the demands of the research project itself to be met. In particular, having 'gone native' it is questionable to what extent a researcher could achieve the degree of detachment, which is necessary to record, code, and analyze data effectively (p.219).

It is very easy for the researcher to relate and struggle with the notion of "gone native" because it is difficult to detach oneself from the environment in which we live and breathe. With the understanding that everyone comes to a research study with a certain amount of biases, researchers may entertain the notion of how one can set aside the biases that they have in order to effectively conduct their role as a researcher. It is difficult to clear your mind of experiences and prior knowledge in order to stay open minded to what the respondents are being observed doing or saying. Christine Griffin in Burgess's edited book (1985) clarified this dilemma more clearly when she states "Research does not occur in a political vacuum, despite the positivist argument that an 'objective' and 'value-free' approach is possible which can transcend political 'biases' and divisions" (p. 102).

Having taught this Toying With Technology course for three years, I knew that I possessed certain biases. I have had experience viewing preservice teachers learn in a constructivist environment and I had an understanding of how students learn and interact with each in this type of environment. As a result of these biases I recognize that I possessed a preconceived notion of how preservice teachers learn and interact in a constructivist environment.

According to Mehra (2002), "This notion of how one's self influences one's research interests is generally the beginning of the discussion on the issue of bias in research" (p. 5). Having been the primary instructor of the Toying With Technology for the course past has provided me with insights and views on preservice teachers' learning that occurs in a classroom that uses a constructivist approach to learning. I have experienced first hand accounts of how students learn about engineering and how they discuss learning in a constructivist environment. According to Mehra (2002),

> A researcher's personal beliefs and values are reflected not only in the choice of methodology and interpretation of findings, but also in the choice of a research topic. In other words, what we believe in determines what we want to study. Traditional positivist research paradigm has taught us to believe that

> what we are studying often has no personal significance. Or, that the only reason driving our research is intellectual curiosity (which is a valid reason on its own). But more often than not, we have our personal beliefs and views about a topic-either in support of one side of the argument, or on the social, cultural, political sub-texts that seem to guide the development of the argument. (p.5)

I attempted to minimize the effects of my biases by inviting the engineering professor connected with the Toying With Technology course to assist in grading preservice teachers assignments. I also actively consulted with a teacher educator from a different in-state institution of higher learner. This individual was completely disassociated with the Toying With Technology course and was able to provide objective insight and perspective by independently coding for categories and themes that validated my emerging themes and categories.

Preparing Tomorrow's Teachers To Use Technology Grant and the TechCo Project

The College of Education at this four-year institution received a 1.5 million dollar Preparing Today's Teachers for Tomorrow (PT3) grant from the Department of Education to support technology infusion into current teacher preparation courses. From this grant evolved the TechCo project, which was a technology rich teacher education program of study where cohorts of preservice teachers completed three years of technology infused coursework. The ultimate goal of this project was to prepare preservice teachers who were confident and competent to assume leadership roles in the incorporation of technology in K-12 classrooms (Thompson & Schmidt, 1999). Gallagher and Bauerle (2003) state that this community of learners was provided with the opportunity to interact and study with teachers who modeled exemplary uses of classroom technology. Additionally, the preservice teachers not only participated in technology problem solving situations, they also interacted and observed K-12 students who themselves were actively using and learning about technology.

The Toying With Technology Course

According to Genalo et al., (1997), the Toying With Technology course was initially offered at Iowa State University during the 1996-1997 academic year. As stated by Gallagher & Bauerle (2003), the main objective behind this course was to offer a comfortable, positive, and stimulating atmosphere to introduce preservice teachers to various aspects of engineering, technology, mathematics, and science. Genalo further stated that the course encouraged and assisted students in designing and constructing hands-on laboratory exercises, which were based upon real world problems constructed out of LEGOs. Additionally, the course expounded upon technological inventions and assisted the preservice teachers with incorporating LEGO and engineering activities into the classroom curriculum. The course further encompassed and encouraged problem solving, exploration, and critical thinking.

Initially, the Toying With Technology course was offered to all majors on campus with the exception of engineering majors due to course enrollment prerequisites. The course curriculum primarily consisted of LEGO robotic exercises. Students were directed to build LEGO robotic cars and perform a series of programming exercises. Other projects that required the students to create "inventions" using the LEGO robotic kits were also a part of the course curriculum. In addition, students in the course worked with groups of K-12 students when scheduled LEGO robotic outreaches were planned in the Toying With Technology lab.

After several years of conducting the course in this prescribed manner, a decision was made to employ a graduate student from the education department. Because the majority of students taking this course were education majors, it was a natural and practical decision to include an education major in co-teaching this course. Ultimately, I was hired to help instruct the Toying With Technology course during the 2000 fall semester and taught a class that consisted of both education and computer science majors. I carefully followed the curriculum that was in place with the exception of having the students create a robotic LEGO golf course.

During the spring 2001 semester, the course was restricted to education majors. Coming from an educational perspective, I was able to provide course curriculum suggestions that would better serve the education students. I was allowed the latitude to make changes to the course to follow a more education pedagogy. As I became more involved with the Toying With Technology course, I recognized that the course would be more beneficial to the students if they were provided with additional engineering activities not directly related to LEGO robotic experiences. Although the robotic exercises were excellent opportunities that provided students with problem solving tasks, the course, in my opinion, needed to provide more engineering related activities. I felt that students should learn about science, technology and engineering while participating in activities that related directly to these areas. While considering course curriculum changes, it was important for me to maintain the original integrity of the course. When deciding on new curriculum, I took into consideration how education majors learn best. From my own experience, preservice teachers learn better when they are actively engaged in authentic hands-on experiences. I researched different approaches to teaching science and technology using an engineering lens. As explained by Gallagher & Bauerle (2003), the Toying With Technology course was ultimately structured and divided into three unique learning experiences. At the beginning of the course, preservice teachers were involved in building and programming LEGO robotic cars. The course then shifted to preservice teachers participating with K-12 students where LEGO robotic exercises were introduced and explored. Finally, the preservice teachers convened back in the Toying With Technology lab to participate in non-LEGO engineering design activities. The activities included but were not limited to silly putty and shrinky dinks, making toothpaste and chocolate asphalt cookies, and creating engineering ABC books. Although non-engineering activities were an important aspect of the course, it truly is learning how to program using the "Not Quite C" programming language that is the crux of the course. In order to better understand the experiences of the preservice teachers, one must understand the process of the progression of their programming experiences.

Programming LEGO Robotics Using "Not Quite C"

Preservice teachers were introduced to the principles of programming LEGO robotics using a pictorial programming language called The Kontrol Zone (See Figure 1.). This particular program was designed by a computer engineering student that worked in the capacity as an undergraduate teaching assistant in the Toying With Technology course. It was noted that in past sections of the Toying With Technology course that the education majors would become extremely frustrated when asked to "just open program 1 and go." In past classes there were limited explanations of why the students were learning programming and how to actually complete this task. The idea behind a pictorial programming language is to introduce elementary education students to the aspects of computer programming in a supportive, exciting, and interactive manner. By using this approach, it allows the students to feel more at ease and acquire several successful programming experiences before moving onto the more advanced programming language of "Not Quite C."

Before preservice teachers could begin programming, the students were instructed to open a Microsoft Word document that contained pictorial instructions on how to build the LEGO car (See Appendix G).

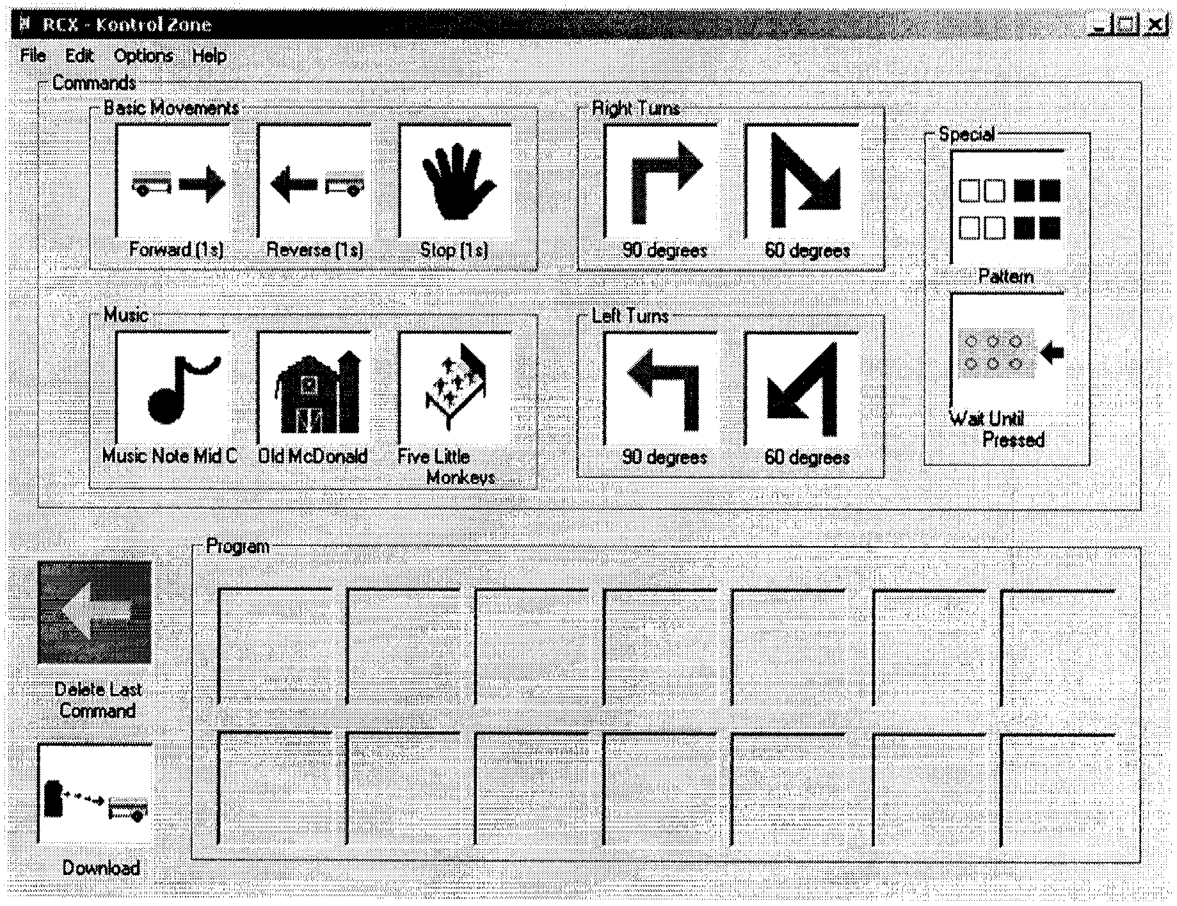


Figure 1. Kontrol zone pictorial programming language

The LEGO pieces were contained in a gray tackle box that was situated in front of each pair of students. The preservice teachers eagerly opened the kit and began building the car. The students built the car slowly and cautiously. After approximately 20 minutes, the students were done constructing the LEGO car. The preservice teachers completed task one and were ready to move forward with programming the LEGO cars using the pictorial programming language of Kontrol Zone. Students spent one day becoming familiar with the Kontrol Zone pictorial programming language.

After surviving the first day of programming using the pictorial programming program Kontrol Zone, the preservice teachers began mentally preparing to start the next phase of their journey, programming the LEGOs using the "Not Quite C" programming language. None of the preservice teachers had previously programmed LEGO robotics. Even though the cohort members successfully made it through their first day of programming, the students were still a bit nervous and standoffish on their second day of class. The preservice teachers were instructed on the purpose of programming. I explained to the girls what programming was, who might use programming in real world applications and how programming would become important to them. After a class discussion on programming, I asked the students to pair up with another member of the course keeping in mind that they would be working with this same person during the next month of programming. It was important for students to work with the same person during basic programming so that the students felt comfortable and could work towards a level of cohesiveness during the problem solving stages with their partner. The first thing I asked the students to do was open the Microsoft word document to once again follow the pictorial directions for building the LEGO car. Cohort members built the car a bit faster than the previous day but still displayed levels of apprehensiveness for not wanting to "fail" during the car building process. All groups were observed meticulously building the car. After all groups had built the car, I then asked the students to open Program 1 of the "Not Quite C" program (Figure 2.)

```
//prog1.nqc
//Description: This program introduces the movement of motors A and C.

task main()
{

//Tells motors A and C to go forward, 5 seconds

OnFwd(OUT_A);
OnFwd(OUT_C);
Wait(500); //Moves 5 seconds

Off(OUT_A);
Off(OUT_C);
Wait(100);

//Tells motors A and C to go backward, 5 seconds
OnRev(OUT_A + OUT_C); // We can start both motors at once
Wait(500);

Off(OUT_A + OUT_C);
}
```

Figure 2. "Not Quite C" Program 1

Preservice Teacher Participants

The preservice teachers participating in this study were previously pre-selected as a cohort or learning community of preservice teachers that volunteered to enroll in a series of technology infused education courses for a period of three years. The twenty-two all female cohort of preservice teachers began participation in this cohort during their sophomore year of college. Of the twenty-two preservice teachers, nineteen were classified as elementary education majors, two were classified as early childhood majors, and one was classified as a secondary education biology major.

The elementary education preservice teachers can be further classified into the following areas of endorsements (See Table 1).

Table 1. Areas of Endorsement (24 Credit Hours)

Area of Endorsement	Number of Preservice Teachers
Art	1*
Science	1
Social Studies	2
Health	2
Special Education	3
English/Language Arts	3
Spanish	4
Mathematics	4

* *This preservice teacher is also working on a social studies endorsement*

From the nineteen education majors, twelve preservice teachers did not have any additional endorsements that they were working towards (ex: coaching, reading, middle school, etc.) Additional endorsements can be defined as any endorsements that preservice teachers might work towards in addition to the primary endorsement required by the College of Education. Preservice teachers are not required to pursue additional endorsements. The following is a breakdown of the additional endorsements and/or minors that preservice teachers were working towards (See Table 2).

Table 2. Areas of Additional Endorsements and/or Minors (Credits Vary by Endorsement or Minor)

Number of Preservice Teachers	Area of Endorsement	Minor
1		Sociology
1	Middle School	
4		Technology
4	Coaching	
6	Reading	

Three of the preservice teachers, two early childhood education majors and one secondary education biology major were not required to pursue areas of endorsement in order to fulfill their degree requirements.

The twenty-two-preservice teacher cohort will represent the case for this research. Three preservice teachers, an early childhood education major, an elementary education major, and a secondary education major were chosen from the twenty-two preservice teachers to interview more in depth for the purpose of gaining a more depth perspective on their experiences in an engineering course. Both the elementary education and early childhood preservice teachers partaking in a series of interviews will be chosen randomly. Because only one secondary education preservice teacher participated in the cohort, this participant will not be chosen randomly. Three preservice teachers were selected from the three different areas of study (early childhood education, elementary education, and secondary education) to provide in depth and diverse views from varying levels of educational expertise. I wanted the preservice teachers to be able to share their stories on how this class affected them as a person, student, and future practitioner.

Although the overall group of preservice teachers was pre-selected, criteria that Lichtman & Taylor (1993) stress when selecting a case was taken into consideration. The authors state that when selecting a case, the researcher should decide what it is that they want to represent. The researcher is to not trying to use the case in order to generalize in the statistical sense but rather exploring a case that represents a "unique" example of other members of the group or case. The cohort of preservice teachers I have chosen to study is unique in the sense that they are classified as a cohort and are identified as such from their sophomore year of college until they graduate. The preservice teachers' involvement in the cohort is also unique to their non-cohort education major peers because of the classification and specific courses that are required, which are different in both content and technology integration.

Data Collection

This case study consisted of collecting data over a period of approximately one year using the following methods: classroom observations and interactions, field observations and notes, reflective journals, WebCT postings, project artifacts, and personal interviews.

Classroom Observations

Classroom observations of the preservice teachers interacting within the Toying With Technology course content were recorded in a journal periodically throughout the semester. The preservice teachers were observed in the natural setting of the classroom during their day-to-day activities. In this setting, I was able to capture "engineering" conversations or conversations related to the engineering type activities in which the preservice teachers were actively engaged. Various classroom interactions between the preservice teachers and between the preservice teachers and instructor were also recorded in a written journal. Because my main responsibility during this course was teaching, I often times would have paper close at hand so that I could write down informal ideas or conversation pieces that occurred between the preservice teachers. Merriam (1998) states that observations must be recorded in as much detail as possible and field notes at the very least must include descriptions, observer comments, and direct quotes. Providing a detailed account of field observations offers the researcher a thorough description of the observations from which to review.

Field Observations

Field observations occurred when the preservice teachers were in the field assisting in K-12 classrooms and assisting with Toying With Technology class outreach events, which occurred both in and out of the regular classroom environment. At times, preservice teachers were asked to assist with class outreaches that entailed having preservice teachers work with K-12 students using both LEGO robotics and LEGO Duplos in elementary classrooms. At other times, preservice teachers were asked to work with K-12 students learning about LEGO robotics in the Toying With Technology classroom. During these outreach sessions, preservice teachers were required to lead LEGO based activities with K-12 students in order to introduce the students in a fun and informal manner to aspects of engineering. Field notes were taken while observing both classroom and field experiences so that I could reflect back on what occurred during the social interactions at outreach events between the preservice teachers and the K-12 students. The notes that were taken during the observations served a dual purpose by first providing a description of the setting, people, and the interactions and secondly to capture the feelings or concerns present (Bogdan & Biklen, 1982).

Reflective Journals

Preservice teachers were asked to keep reflective journals for the first month of the course to record their problem-solving strategies (See Appendix D). During the first month of class, preservice teachers were actively engaged in learning the computer programming language "Not Quite C." The majority of preservice teachers had never had the opportunity to work with computer programming so it was fundamentally important that the preservice teachers documented their problem-solving strategies to assist in the metacognition process or the thinking about one's thinking process. The journals served as powerful resources to communicate feelings and reactions to the frustrations and triumphs of first time programming that many preservice teachers faced.

WebCT Postings

During the Toying With Technology course, preservice teachers were asked to participate in a WebCT environment that supplemented the regular classroom experiences. Preservice teachers interacted with the following WebCT components: lesson plan resources, syllabus, discussions, real time chats, outreach event schedule, lesson plan criteria and an ABC Engineering Book project. Some areas of the WebCT environment such as the lesson plan resources, syllabus, outreach schedule, lesson plan criteria and the ABC Engineering Book project were included in the WebCT environment to be utilized as an informational component. Preservice teachers were not required to "actively" participate within these areas but rather reference them when needed. Other areas of the WebCT environment such as the discussion area and real time chats were intended to be interactive cyber areas where preservice teachers could visit and participate in virtual conversations with other students. Preservice teachers were required to post in the discussion area at least once per week but upwards of twice or more a week. Preservice teachers were also required to partake in real time chats several times during the course. As the instructor, I also participated in the discussions by contributing as a group discussion leader. When necessary, I replied to participant responses and kept the dialogue active. Even when I did not actively contribute to their dialogues, the preservice teachers knew that I would take on the role of the "lurker" in the discussion areas. Conversations that emerged out of the discussion section were recorded in the WebCT environment and were printed in hard copy form so that I could analyze them at a later date.

Project Artifacts

Throughout the semester, preservice teachers were actively engaged in classroom assignments and projects. The project artifacts that preservice teachers produced included the following: lesson plans, LEGO egg drop project, LEGO Harry Potter miniature golf course, an engineering career fair paper, and Engineering ABC books.

Preservice teachers were required to write three lesson plans that included the incorporation of engineering principles. The lesson plans were due at the beginning, middle, and end of the semester. Preservice teachers were required to apply what they were learning in the class and apply it in lesson plans for the age level of K-12 students that they planned on teaching in the future.

The preservice teachers also created a LEGO egg drop contraption using the LEGO Mindstorms robotic kit that would move a raw egg from the table to the floor without human intervention. Preservice teachers worked on this particular project for a total of six hours.

Similar to the robotic LEGO egg drop project, preservice teachers were assigned a LEGO Harry Potter miniature golf course project (See Appendix J).

The preservice teachers were required to work in teams of four to create a robotic golf hole that contained two moving parts that were controlled by the LEGO Mindstorms "brick" that corresponded to a chapter in the Harry Potter and the Chamber of Secrets book. The preservice teachers spent eleven hours crafting their golf holes. The preservice teachers used as many LEGO pieces as they needed along with non-LEGO pieces to create interactive and aesthetically pleasing golf holes. After the golf holes were created, the preservice teachers spent time playing on the Harry Potter miniature golf course. The project was archived by digital pictures and video that represented each golf hole.

Preservice teachers were required to attend a local engineering career fair to obtain information on the field of engineering and to report on the capacity in which education majors could work in this field. The career fair was held at the local university coliseum where many engineering companies were represented. The preservice teachers wrote reports chronicling their time spent at the career fair and reporting what they learned. Preservice teachers were also required to gather as much information as possible from the engineering companies in order to be able to contribute to their upcoming project of researching and authoring an engineering ABC book.

The engineering ABC book project required teams of preservice teachers to create an ABC engineering children's book by researching an area of engineering that was of interest to them. Preservice teachers were required to locate engineers in real world work experiences that would be able to provide information to contribute to their books. In addition, preservice teachers were advised to seek additional venues for information to contribute to the ABC book and to compile that information as a professional product to share with the class. Before the preservice teachers could turn in their projects, the books were required to be piloted at the target audience for readability and interest.

The projects that preservice teachers created during the semester served not only as physical artifacts upon which interpretations could be made but also where participant understanding of engineering principles and concepts could be assessed.

Personal Interviews

Three preservice teachers from varying majors in the field of education were chosen to interview more in depth in order to gain a more compressive insight about their thoughts and ideas. The preservice teachers were randomly chosen according to their area of study. One participant from each of the following areas were chosen: Early Childhood Education, Elementary Education, and Secondary Education and were interviewed on three separate occasions throughout the semester.

For the exploratory purpose of this research, a semi-structured format of interviewing was utilized throughout the interview process. The initial interview for each respondent lasted approximately one-hour and consisted of a variety of open-ended questions (See Appendix E). The first interviews were transcribed immediately so that emerging themes within the interviews could be identified.

The first interview location for each respondent was chosen according to the respondent's place of interest. I wanted the preservice teachers to feel comfortable during their interviews so that they could focus on the interview instead of being nervous. All three preservice teachers chose to meet at a local coffee house located in campus town. Upon entering the establishment, there were many people talking, eating, drinking coffee or other beverages, and listening to the music that was playing in the background. I met with each respondent individually and each time we tried to chose a place in the coffee house where we could get as far away from the noise as possible. When I reviewed the tape transcripts, I found that the coffee house was really noisy which made it very difficult to hear and transcribe the conversations.

The second interview also lasted approximately one-hour. This interview was more structured and questions were directed according to the emerging themes that were found from the first transcribed interview. This initial interview was transcribed within several weeks of the interview. The final interview occurred approximately one year after the preservice teachers had completed the Toying With Technology course. This interview lasted approximately one-hour and focused heavily on whether or not the preservice teachers' views of engineering, science, and/or technology had changed. In addition, the preservice teachers were probed to see if they had employed any activities or knowledge that they learned in the Toying With Technology course in their classroom practicum experiences.

A variety of data collection methods occurred throughout the study in order to gather an assortment of data as different preservice teachers expressed themselves in diverse ways. Multiple sources of data were also collected so that I could decide which topics I would pursue in more depth during the personal interviews. This strategy helped to ground how the personal interviews proceeded. More specifically, I reviewed informational sheets that I had distributed to the preservice teachers throughout the semester and looked for topics that presented themselves through the informational sheets. For example, one sheet asked questions pertaining to their thoughts on the field of engineering. From this sheet, I was able to identify key pieces of information that I wanted the interviewees to go more in depth in during the personal interviews. The information sheets were gathered from the entire class, not just the responses of the interviewees.

Data Analysis

Qualitative data analysis transforms the data into findings (Patton, 2002). The researcher continues to state that there is no real formula that exists for that transformation; there is guidance, but no true recipe. The qualitative data analysis process is really not a very well specified process (Robson, 2002) and considered as much art as it is science (Babbie, 2001). Moreover, there are no cut-and dry steps that guarantee success.

I maintained a very pragmatic view towards data analysis and the data analysis process. I knew that this would be a slow and arduous process so I allowed myself plenty of time to analyze the plethora of data that I had acquired from the preservice teachers. Towards the beginning of the data analysis process, I had contemplated using a data analysis software program to help assist me with the coding process. As the time drew closer for me to actually start the process of data analysis, more particularly coding, I decided that I wanted a more personal relationship with the "raw" data. I was skeptical as to the depth in which the data analysis program would be able to effectively assist in the organization of the data. I started the coding process by literally immersing myself in stacks of papers. This arrangement helped me to classify the data in such a way that I was able to sort and code in a more desirable order.

Data were initially sorted and analyzed according to data collection sources: classroom observations and interactions, field observations and notes, reflective journals, WebCT postings, project artifacts, and personal interviews. I examined all of the materials that I had thoughtfully and purposely collected from the preservice teachers and began sorting the materials according to sources. Fortunately, as the instructor of this course, I was able to collect and accumulate an insurmountable amount of data but I was then faced with a dilemma of which data to analyze more in depth. After sorting the data according to sources, I was presented with a manageable amount of data that required coding. I sorted the data into the following three categorical stacks: early semester, mid semester, and late semester.

Early semester data included: engineering questionnaire, journals, WebCT discussions, and robotic assignment sheets. Mid semester data consisted of: WebCT discussions, personal interviews, and a robotic assignment sheet. Late semester data consisted of personal interviews, WebCT discussions, Harry Potter robotic golf course reflection, and an engineering questionnaire.

The Coding Process

As stated by Coffey & Atkinson (1996, p.4), ". . . segmenting and coding of data are often taken-for granted parts of the qualitative research process." In addition, all researchers need to possess the skills in order to organize, manage, and retrieve the most meaningful bits of data. According to Chenail (1995) data, which was so painfully collected, should 'be the star' in the relationship. Coding is the key process during data analysis because it assists with classifying or categorizing individual pieces of data that is coupled with some type of retrieval system (Babbie, 2001). Furthermore, one should think of coding as a physical act; the old-fashioned act of filing that the researcher uses a set of file folders with code names on the tabs and physically places the data in the appropriate file folder.

Before I started the coding process, I followed the guidance of Patton (2002) who began by reading through all of his field notes and interviews and made comments in the margins that contained notions about what he could do with the different parts of the data. I then initiated the personal journey of coding by examining data beginning with the early semester stack. I purposely chose to sort data according to time periods in order to establish a hierarchy system. It was important to analyze the data according to dates to better organize the large amounts of data that was collected and to begin to put the whole analysis together from beginning to "end."

To initiate coding of materials, I highlighted key words or phrases on the data pieces. For example, the course reflection assignment asked the preservice teachers four questions. I numbered all the assignment sheets pertaining to this set of data and assigned the number to a particular preservice teacher participant. I then methodically read through each question on the four-question assignment sheet, one participant at a time. I highlighted key phrases or words within their responses. After all course reflections were highlighted, I transferred the key words and phrases into the program Microsoft Excel. I included the four questions at the top of the spreadsheet and then included the key words or phrases under each question (See Table 3).

Table 3. Example of raw email data entered into a microsoft excel spreadsheet

Data taken from an Email Feedback	Question 4: Do you think it is important for (K-12) students to gain an understanding about engineering?			
Respondents	**Yes**	**No**	**Respondent Answer 1**	**Respondent Answer 2**
1	1		Knowledge is power	So they feel less threatened
2	1		Kids need to know that engineering isn't a "smart" major	It consists of more than you would think
3	1		Student exposure to many different professions	
4			No Response	
5	1		Understanding about the many forms of engineering	
6	1		More opportunities for kids to learn about the world in which they live	
7	1		Engineering is all around us	
8	1		To erase ignorant perceptions of engineering	
9	1		I see how valuable they are	Involves our everyday lives
10	1		Everything around is based on engineering	
11	1		Engineers do many things	Fun career
12	1		So they feel it is a real possibility for them	
13			No Response	
14			No Response	
15	1		Close the gender gap	
16	1		Show them that engineering is everywhere	
17	1		Students should be exposed at young age	
18	1		Learn about career opportunities	Especially girls
19	1		It will give them more opportunities	
20	1		Engineering is everywhere	
21	1		Engineering is everywhere	
22	1		Broaden their horizon	Give them new information

After all data were recorded in the software program Microsoft Excel, I printed out the data filled spreadsheet. Instead of continuing the coding process in Excel, I choose to work with the spreadsheet on paper. I searched for common themes using the phrases and key words that were recorded from the preservice teachers' answers. All preservice teacher assignment data sources were coded in the same manner.

For the interview transcripts, I used Christine Griffin's (as stated in Robert Burgess's edited book (1985)), process of evaluation:

> Following the tape transcription, I went through all the field notes and transcriptions to categorize the material according to a series of topic headings. These were designed to cover the main research areas; to be exhaustive with the minimum of overlap; and to be fairly manageable with negligible loss of detail. This categorization was recorded on a card index system, which shaped the final analysis. It included additional topics arising from the fieldwork (p. 104).

Validity

According to Merriam (1988), internal validity is centered on whether the research findings actually agree with reality and in this particular case, the concern lies in the reality of the individuals that were interviewed or observed. To insure accurate data analysis and interpretation of the data in this study, the following measures were in place: triangulation, member checks, and peer-examination.

Triangulation

Triangulation is the process of using multiple sources of data and methods to confirm findings (Merriam, 1998; Lincoln & Guba, 1985). Triangulation enhances accuracy of interpretation and confirms that the data collected is not due to chance or circumstances. Yin (1994) states that by using triangulation in a case study approach, findings or conclusions are more likely to be more convincing and accurate if they are based on several different sources of information following a corroboratory mode. Triangulation in this study meant using data from many different sources: classroom observations and interactions, field observations and notes, reflective journals, WebCT participation, artifacts, and personal interviews. As a researcher, I wanted to use a variety of data sources to ensure that I was able to provide a comprehensive description of this study.

Member Checking

Member checks occur when the researcher returns to the individuals that were interviewed to test whether or not they think the interpretations of the data collected from them seem like adequate representations of what they said or experienced (Lincoln & Guba, 1985). Creswell (1998) states the member checking is sharing interview transcripts, analytical thoughts, and/or drafts of the final report with research preservice teachers to ensure that you are representing them and their ideas accurately. Member checks required taking data back to the preservice teachers to confirm if the interpretations were realistic (Merriam, 1998).

Lincoln & Guba argue, "If the investigator is to be able to purport that his or her reconstructions are recognizable to [those studies] as adequate representations of heir own (and multiple) realities, it is essential that they be given the opportunity to react to them" (1985, p. 314).

There were several instances where the respondents did not perceive interpretations from my initial work the same so clarifications were made accordingly to elucidate any misinterpretations.

Peer Examinations

Peer-examination utilizes a colleague to comment on emerging findings (Merriam, 1998) as well as an external reflection and direct input on your work (Creswell, 1998). Lincoln & Guba (1985) refer to this process as peer debriefing and state that one uses colleagues as sounding boards for one or more purposes. It can be further defined by sharing ideas about procedures and logistics in the field to get advice and to check the dependability of ways in which to proceed. As stated by Lincoln & Guba (1985), the peer debriefer must:

1. challenge the researcher and the interpretations
2. help the researcher to voice her values and feelings
3. formulate methodological decisions
4. apprise the researcher of any ethical dilemmas or transgressions
5. listen fully and with an open mind

For the purpose of this study, I conversed with a colleague at a private institution that lacked attachments or biases towards this study. This individual has a background in working with educational technology and preservice teachers and science education so she was able to readily provide me with valuable ideas, insights, and rich conversations.

Data Analysis Framework Model

As I was immersed in the data organization process, I felt the desire to locate a model or matrix that would assist my organization of thoughts and to help support me with this overwhelming process. Cole (1994), also shared similar frustrations and struggles with this same process. She tells of feeling confused and overwhelmed with the prospect of analyzing the data that she had so carefully and thoughtfully collected. Cole states; "There comes a time when a researcher has to face the truth. Gathering research data is a lot more fun than analyzing and reporting it" (¶ 4). I could directly relate to Cole's experience and upon further reading of Cole's article, I discovered that she describes a matrix that would prove to be useful during the data organization process by providing a comprehensive framework to organize my data. The model, Chenail's Qualitative Matrix, (Figure 3.) allowed me to organize expected and unexpected findings related to my research questions.

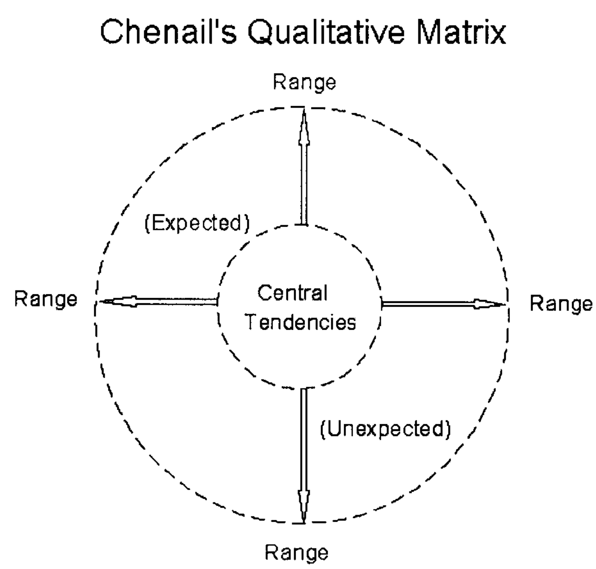


Figure 3. Chenail's Qualitative Matrix

Cole describes the matrix as being able to insure a relationship between data presentation, data analysis and the literature review. In addition, the matrix provides a conceptual framework for coding the data and while suggesting a map for reproducing analyzed data into an organized pattern that connects the findings of the research with the review of the literature. Cole presents and describes the four main concepts of this matrix as the following:

1. **Central Tendencies**-describes how the data converge into the research participants' themes or categories
2. **Ranges**-allows for the differences within the categories to be discussed
3. **Expected**-refers to data that confirms the ideas of the authors in the literature review and/or the researcher's assumptions
4. **Unexpected**-refers to data that departs from the authors' ideas in the literature review or the researcher's assumptions (Cole, 1994, ¶ 1,4,7).

Cole's matrix was used to organize six three-ring binders of data. The expected data according to Cole, "refers to data that confirms the ideas of the authors in the literature review and/or the researchers assumptions" (¶ 9). The unexpected data "refers to data that departs from the authors ideas in the literature review or the researchers assumption (¶ 10). I used the matrix as a visual organizational system to sort expected and unexpected data.

During the Toying With Technology course, the preservice teachers described various aspects of problem-solving, therefore, problem-solving became a central tendency that was coded into a theme as shown in Figure 4.

Positive Experiences

Process used when Problem Solving in Groups

Process used when Problem-Solving Alone

Negative Experiences

Continue to Report Problem-Solving Strategies Throughout the Course

Opportunity to Discover the Unexpected

Problem Solving

Figure 4. Chenail's Qualitative Matrix Showing Organization of Problem-Solving

However, within the central tendency of problem-solving, students shared and described very different experiences. Students reported problem-solving strategies in terms of both positive and negative experiences. In addition problem-solving during group situations was described as being very different than problem-solving when alone. Students also describe problem-solving as a tool that they will use and teach in future classroom experiences. The above examples illustrate the different ranges within the central tendency of "problem-solving."

According to Cole, the terms expected and unexpected are used to organize the data arrangement. I predicted that preservice teachers would describe problem-solving experiences because I had asked that they write about their problem-solving strategies in student journals. However, what was unexpected is that preservice teachers continued to report on problem-solving strategies throughout the course. As a result, students continued to discuss and report their problem-solving experiences. Since it was unexpected, problem-solving was not an emphasis in the literature review. This unexpected finding is supported by Chenail's Qualitative Matrix where researchers are provided with the opportunity to discover the unexpected opposed to staying focused only on what was supported through literature searches and previous observations (Cole, 1994).

The way in which Cole explained the use and purpose of the matrix influenced and impacted the way in which I structured and performed my data organization. Cole expressed the following reflection in her article,

> In my own research, the matrix reminded me to explore and report all of the ranges and differences between the preservice teachers' stories instead of trying to quickly reduce the data. I fought the inclination to wrestle the research findings into tidy categories organized by only the similarities or central tendencies of the stories. I welcomed the serendipitous in the narratives and placed the unexpected data side-by-side with the expected results. In doing so, I believe my dissertation research possesses a certain robustness that would have been weakened without the ideas from the matrix. Of all the academic books and articles I read, it was the pizza-stained napkin that guided me through the research maze (Cole, 2001, ¶ 8)

Similar to what Cole experienced, the research data began to show an initial structure of themes. Once the central tendencies became clear, the use of poster size paper began the next process of analyzing the data. I mounted large poster sized paper on several walls in my "research room" to aid in the data analysis process (See Appendix F). Next began the process of sorting through the spreadsheet data. The data from the spreadsheets was converged to form initial emerging themes.

Each poster depicted one of the central tendency themes. As I read through all data sources on the spreadsheets and matched them with the coded data source, I was able to explain ideas that confirmed my assumptions as well as research questions. Ideas and explanations were written in notation form beside data findings on the posters. As I progressed through this process, arrows and lines were drawn to connect thoughts and explanations while narrative explanations were written in the margins to begin early stages of reporting findings. This process continued until all data were analyzed and displayed on the wall posters related to emerging themes. The unexpected findings emerged as a sub-set of several themes and were color coded for emphasis. The wall posters became an iterative process for restructuring themes into categories until I reached saturation.

Summary

We currently live in a highly technological society where technology is only gaining momentum. As educators, it is our responsibility to educate our youth to face challenges in the world and to be prepared for this challenge. Youth need to be informed consumers of the world in which we live in order to be effective contributors to society. However, teachers are reporting that they feel unprepared to teach in this technological society and report feeling inadequate to teach both science and technology. Case study research provides the much needed insight into teaching and learning. According to Simons (1996), case study research is unique in its capacity for understanding complexity in particular contexts.

It is no longer acceptable to graduate teachers that are ill equipped to teach science and technology. In this study, a cohort of preservice teachers was understood as having a voice to share about science, technology, and more specifically engineering. It is important to listen and take heed of the stories that these future teachers have to tell. If one listens closely enough, their stories speak volumes about their perceptions on learning in a constructivist based engineering course and how they report on how they will use what they have learned in the future.

Throughout this research endeavor, I participated not only as the researcher, but also as the instructor of the Toying With Technology course. I strove to accurately portray and report the words of the preservice teachers without bias, in addition to involving them in a research process that allowed them voice and empowerment. The methodology presented and described in this chapter was intended to acquaint the reader with a description of the research techniques, a description of the Toying With Technology course, preservice teacher preservice teachers, and data collection and analysis procedures that were used in this study.

CHAPTER IV

FINDINGS AND DISCUSSION

The twenty-two female preservice teacher cohort members that participated in a semester-long engineering course aimed at preparing future teachers in the areas of science and technology informed the findings of this study. Data were collected from the following sources: classroom observations and interactions, field observations and notes, reflective journals, WebCT participation, artifacts, and personal interviews. This chapter is organized around themes relating to the research questions to help describe how preservice teachers participated and reflected upon experiences in an engineering course that used a constructivist approach.

The following themes were identified through data analysis of the above data sources: Developing Perceptions of Engineering, Science, and Technology, The Language of Learning: Learning How to Learn, and Applying Engineering in K-12 Classrooms. Table 4 illustrated the three identified themes with the corresponding categories.

The findings from this study tell the story of what occurred during the preservice teacher's involvement in the Toying With Technology course. The themes emerged from the data as a result of analyzing student journals, WebCT, interviews, and classroom assignment project sheets. The findings of this study are discussed from the emerged themes to tell the story of the participation and involvement of the preservice teacher cohort participants in the Toying With Technology course. The first theme, Developing Perceptions of Engineering, Science, and Technology, is discussed using a chronological framework. A chronological framework allowed for a sequenced story of the participants' changes in perception as a result of experiencing the Toying With Technology course. Following the chronological framework of the participants' perceptions, findings from two additional themes will be reported. These themes are not dependent on a chronological framework.

Table 4. Themes with corresponding categories

Developing Perceptions of Engineering, Science, and Technology	The Language of Learning: Learning How to Learn	Applying Engineering Ideas and Concepts in K-12 Classrooms
Beginning of the Semester	Learning Problem-Solving Skills through Course Activities • Programming LEGO Robotics • Problem-Solving • Communication	Teaching Engineering in Field Experiences
Mid Semester	A Constructivist Approach to Learning • Understanding a Constructivist Approach to Learning • Absence of Grading in a Constructivist Classroom • Constructivism as an Interactive Process • Active Exploration of Materials In a Constructivist Environment • Application of Engineering Principles in a Constructivist Classroom • Self-Efficacy and Constructivism	Desire to implement Engineering in K-12 Experiences
Late Semester		

Cohort Participants

The preservice teacher students were previously introduced in Chapter III to establish an initial relationship to the Toying With Technology cohort. Study participants are reintroduced in Chapter IV, assigned a pseudonym name to maintain confidentiality, and categorized by their academic major to provide further clarification and personalization to the preservice teacher participants (See Table 5).

Table 5. Cohort participants identified by major by pseudonym names

Early Childhood Education	Elementary Education	Secondary Education
Morgan	Alison	Keisha
Tiffany	Angie	
	Ann	
	Brooklyn	
	Carmen	
	Chelsey	
	Emily	
	Jane	
	Jessica	
	Jill	
	Joy	
	Kaitlyn	
	Karen	
	Kris	
	Madison	
	Mandy	
	Mary	
	Pam	
	Eve	

Providing pseudonym names to the cohort members helps create a mental image of the participant while providing a more concrete connection to classroom occurrences experienced throughout the findings of this study. Additionally, pseudonyms help to provide a clearer readability of the written word. "Words can learn about that elusive, highly subjective world of personal perceptions, opinions, feelings, and attitudes" (Champion, 2002, pg. 64). According to Gall, Borg, and Gall (1996), creating pseudonym names draws the reader into the subjects' world to achieve a more realistic understanding of the participant's phenomenological reality. Each participant is unique, maintains a diverse point of view, and speaks independent of others. A pseudonym allows for the analysis of diverse as well as common points of view (Gall, Borg, & Gall, 1996).

Findings

During the data analysis process, three distinct themes were identified. Perceptions of Engineering, Science, and Technology was identified as a theme to answer research question one listed below. The Language of Learning: Learning How to Learn answered research questions two, three, and four. The last theme: Applying Engineering in K-12 Classrooms answered research questions three and four.

1. How do preservice teachers' perceptions develop while participating in a course featuring engineering principles?
2. As a result of this engineering course, how does the use of a constructivist approach in teaching and learning effect preservice teacher's perceptions of science, technology, and engineering?
3. How do preservice teachers describe personal experiences with engineering based projects?
4. How do preservice teachers describe implementation of what they have learned about science, technology, and engineering?

Developing Perceptions of Engineering, Science, and Technology

The theme Developing Perceptions of Engineering, Science, and Technology was used to describe the findings of how preservice teachers developed their understanding of the field of engineering, science, and technology. The following three categories were identified from the data as contributing to the theme of Developing Perceptions of Engineering, Science, and Technology: Beginning of Semester, Mid Semester, and Late Semester. This theme is told using chronologies in order to provide a more detailed and comprehensive account of the development of students' perceptions about engineering as the semester progresses.

Beginning of Semester

On the first day of class, before any course materials were presented to the preservice teachers, I presented and passed out a questionnaire, which asked the following three questions:

1. What is engineering?
2. What does an engineer do?
3. Do you ever remember learning about engineering in school? If so, what memories do you have?

I asked the preservice teachers to fill out the questionnaire by providing as much detail as possible. After analyzing the questionnaire and synthesizing their responses the findings revealed that many preservice teachers possessed very rudimentary ideas about engineering. Many students responded to research question one by simply identifying specific fields in engineering. For example when Jill responded to research question one, she answered the question by simply listing fields of engineering such as: mechanical, electrical, architectural, computer, and structural. When answering the same question, Madison also chose to list the following specific fields of engineering: mechanical, chemical, aerospace, construction, computer, and agricultural. These findings demonstrated that the majority of preservice teachers tended to generate simple one-word lists when asked to describe engineering fields which led me to presume that if students were able to describe attributes associated with the different types of engineering they unquestionably would have written those descriptive qualities on the questionnaire.

Additional findings indicated that the majority of preservice teachers were also able to list minimal attributes associated with the field of engineering. For example, students identified engineering using words such as building, creating, designing, and inventing. Chelsey shared what she perceived the field of engineering meant to her, engineering is "thinking and creating new things- designing and inventing." Pam shared the following similar ideas, "Engineering is the inventing and building of objects-uses technology." Karen also contributed comparable ideas when she stated, "Engineering is an enormous field that involves many aspects of life. It involves designing, building, creating, and other aspects."

For the most part, the majority of preservice teachers were able to identify basic characteristics of engineering. The preservice teachers described in limited detail what they meant by "building", "designing", or "creating" possibly because the concepts and principles of engineering were too far out of reach at this point in the course. Many preservice teachers began to grasp basic concepts of engineering and were not yet able to discern an entire overview of the profession as well as articulate the relationship of engineering to education. Similarly, preservice teachers over generalized ideas in order to attempt to make connections to previous learning experiences. Their use of a single engineering term or concept was used for multiple meanings. This strategy for making connections might have been the only way that the preservice teachers could discuss at this point in their educational careers as students.

Related to findings of the questionnaire, students also had trouble understanding the relevance of engineering in K-12 education. During the second week of class, I initiated a discussion on the importance of teaching K-12 students about the field of engineering where I presented the idea that educators should examine present K-12 curriculum to see how engineering could be effectively incorporated. It was difficult for the students to verbalize and discuss why they considered engineering principles important to teach to K-12 students. During the class discussion, one preservice teacher commented, "Why should we have to teach about engineering any more than we should teach about other professions such as doctors, lawyers, and dentists."

Almost all of the preservice teachers were unable [at this point in their educational career and previous experiences] to recognize the association for incorporating engineering concepts into the K-12 curriculum. Once the preservice teachers were able to internalize what they had learned in the Toying With Technology course, I hoped that they would have a stronger understanding of how to use engineering concepts to provide real world problems for their own students to learn both science and technology.

Towards the end of the first month of the course, a preservice teacher began to perceive how engineering became relevant in her life. Jane stated,

> I find it [engineering] to be very intriguing. I now find myself truly examining the functions of machines around me from the simplest (a doorknob) to the complex (a computer and printer operating). I really feel like this class has opened my eyes to the "world of engineering" that surround us and allows me

to better appreciate the advances that these people make to have our lives be better improved.

Many preservice teachers began to view engineering as a critical component of their daily lives in terms of how the scientific process is used for such things as operating a microwave oven. Engineering was no longer considered an abstract idea. Many students were able to begin generating general connections to daily living experiences and even created opportunities for thinking about how engineering related in their own personal worlds like the example that Jane described above.

Mid Semester

During the mid-semester portion of the Toying With Technology course, "normal" classroom activities shifted to more unfamiliar projects. Preservice teachers participated in more difficult programming LEGO robotic projects such as the Harry Potter miniature golf course and teaching K-12 students basic programming using the "Not Quite C" language. At this point in the semester, preservice teachers were no longer required to keep and write about how they programmed and problem-solved. The cessation of journals was a major shift in current course activities. Students demonstrated an appreciation for having been provided the opportunity to articulate feelings in written form. Students were now required to actively participate in an online WebCT environment, by postings reflections and participating in real time virtual "chats" with classmates.

Perceptions of engineering began to shift from basic and simplistic to more formal and complex understandings of engineering. A significant number of preservice teachers began to openly express what they had learned about engineering and how engineering related to their everyday life experiences. In a WebCT posting Ann wrote,

> My personal perceptions of engineering have changed in many ways since the beginning of this class. I didn't really know what to expect. I didn't know that engineering had so much to do with things that I take for granted everyday, from complex things like cars and computers, to things that seem simple like the food that I eat and the shampoo and toothpaste that I use everyday. I had no idea before that engineering was so important and that it is everywhere. Toying With Technology was valuable to me in this new understanding of the wide spectrum that is engineering. If I hadn't had this class, I never would have thought about engineering, even though I should have because it is so important and needs to be appreciated.

Ann provided a wonderful analogy of how engineering had changed her world. She became more receptive to the ideas of how engineering affected her everyday living to be able to create connections to previous knowledge. Ann was able to make these connections because she was learning about different fields of engineering in class. For example, I had the students participate in an activity where they were making toothpaste in order to discuss what a chemical engineering might do as part of their job duties. Ann may not have a well-developed level of understanding equivalent to that of actual engineering students, but I believed that she demonstrated improvement in regard to engineering in general. Joy posted a follow up comment on WebCT to Ann's initial posting. Joy wrote the following reflection,

> Ann, I completely agree with you about appreciating engineering far more now than you ever have before. I have more respect for engineers now. I also agree that it is neat to have a broader perspective of all the ways engineering influences us everyday from the toothpaste we use to the gum we chew. I am

thankful we have been exposed to engineering as a concept we can teach because I think kids would benefit so much from having engineering in their curriculums.

Similar to Ann's response, Joy supported Ann's statement regarding the appreciation of engineering and the realization of how engineering affected our daily lives. Joy had a tendency to trivialize engineering by using language like "neat." However, Joy did perceive and reported a value of supporting engineering in K-12 education. It was also apparent from both Ann and Joy that the Toying With Technology course had a direct influence on the way in which they both had previously thought about engineering. They no longer viewed engineering as something that you read about or something that only people good in math and science could interact with. Mary also shared common thought with both Ann and Joy. Mary wrote the following posting in WebCT, "I have noticed that I pay attention more to roads, bridges, buildings, and cars and find myself just thinking (briefly) about how many engineers it must have taken to make and think up something like that."

The Toying With Technology course allowed the preservice teachers the freedom to be creative. The course literally broke down the formality of the nature of engineering. Although many students described engineering as math-and-science-based with expected technical terminology, other students described engineering by using the word "creative". In a WebCT posting Joy described how the field of engineering was creative,

> I see engineering as a far more creative field now than I once did. Whereas I used to visualize engineers sitting in front of computer screens, I now know they are involved in large projects that require cooperation on many different levels.

Carmen also posted a similar reflection on WebCT that aligned with Joy's thoughts on engineering as a creative discourse.

> Well, my perception of engineering was a person with all brains sitting at a desk making up impossible equations to design or build something. I am sure that a problem-solving characteristic needs to be present and that also, yes [sic] it may take brains but it also needs a creative mind to be able to come up with some of the ideas that engineers do.

Clearly, preservice teachers believed that the Toying With Technology course, which was designed around engineering principles, was creative. It may be that not all engineering, science, and technology content lent itself to creative experiences. Carmen asserted, "I think it [classroom activity] would really value the students to really put their creative thinking caps on." For example, several preservice teachers reflected on a particular classroom activity called "asphalt cookies" in terms of the creative manner in learning about civil engineering (See Appendix J). Students were read the children's book *The Road Builders* and then provided with ingredients to make asphalt cookies in order to learn about the importance of roads and road composition (i.e. asphalt) to introduce them to one aspect in the field of civil engineering. An excerpt taken from one of the personal interviews, Morgan provided a brief insight into the asphalt cookie activity by explaining how a creative activity might enhance a K-12 student's learning experience,

> ...when you teach us with the lessons I think I understand more about how it actually does fit into the real world. That you just don't build things, and with little, [sic] with students when they are younger, they won't understand, oh

we're building theses LEGOS-big deal. But when they are like Oh we're making asphalt, that's on the road. We drive on that all the time.

Towards the end of the mid-semester activities, a significant number of preservice teachers continued to construct more sophisticated perceptions of engineering. I continually challenged students to develop their ideas about engineering, science, and technology and to create real world connections. Their developed perceptions were evident in one of the WebCT postings where Brooke shared a lesson plan that contained a personal connection where she wrote a song to teach and educate second grade children about polymers:

Setting the stage: Sing this song to the tune of The Farmer In the Dell

Some polymers are here, some polymers are there, they help us in our school and home, we find them everywhere.

We'll look around the school, and see what we can see, and name all the polymers, that help you and me.

Now we're in our class, and polymers we'll find, they help us in our work and play, to better use our mind.

Let's think about our homes, each room that we live in, and name all the polymers, that help us and our kin.

It appeared that many preservice teachers were developing an improved overall perception of engineering principles and demonstrated the ability to create connections with other classroom subjects as well. The above example depicted one particular student that was able to formulate a connection about the elements of polymers (engineering) connected to forms of music and created a song about polymers. Many students were beginning to synthesize knowledge and create connections with familiar ideas of their own.

Late Semester

Towards the end of the semester, the vast majority of preservice teachers viewed engineering as "more fun" than it used to be. The enjoyment of engineering was found in their descriptive explanations of what they had learned. Preservice teachers continued to describe engineering principles as elements of their daily lives. Jane wrote the following reflection for an end of the semester course questionnaire, "Engineering is all around us and I feel like I have gained a greater appreciation for what engineers do. They make improvements in so many different aspects of our lives that I never really considered before."

Throughout the course students exhibited a developmental progression, as they were better able to describe and report on engineering. The way in which preservice teachers described the field of engineering was more thorough and thoughtful. Students possessed the ability to describe different engineering careers and could dialogue what those careers entailed. Most importantly, students were able to recognize how engineering related directly in their world and their resulted disposition was a marked difference in their appreciation for the impact of engineering in our world. Jill provided an insightful documentary in her end of year course reflection,

> Coming into this class I knew very little about engineering. This class taught me about the different types of engineers and what they do. I learned about their problem solving process and how it compares to mine. I was able to experience what engineers do through the projects we did. I was able to be in their "shoes" for a day.

A developmental progression of preservice teachers' perceptions, while critical in their maturity of thinking about engineering principles and concepts, was still far from being developed. The preservice teachers lacked the capabilities of formulating those principles for learning and teaching purposes. Students clearly needed to develop further knowledge and perceptions surrounding engineering concepts so that they were able to acquire the skills and competencies demonstrating what they knew. While the building of perceptions was critically important for preservice teachers, it was a very small part in their ability to develop appropriate knowledge and skills regarding practice.

The Language of Learning: Learning How to Learn

The theme of The Language of Learning; Learning How to Learn was used to describe the findings of how students made a change in the way that they thought and operated during their interactions and experiences in the Toying With Technology course.

The Language of Learning theme described the process of learning how to be a learner. When preservice teachers participated in the Toying with Technology course, they were actively engaged in the discourse of language allowing for comprehension, speaking, and reciprocal dialog, while they focused on the intent of their communication. The following two categories were identified from the data analysis process as directly contributing to the theme of The Language of Learning: Learning Problem Solving Skills Through Course Activities and A Constructivist Framework for Learning.

Learning Problem Solving Skills Through Course Activities

A significant amount of data was derived from the LEGO robotic programming exercises and activities. Programming LEGO robotic inventions was an integral and significant component of the course, which directly contributed to a multitude of descriptive data. Throughout the semester, preservice teachers were involved in a variety of classroom activities and projects ranging from programming LEGO robotics, assisting K-12 students with programming LEGO robotics, and participating in engineering activities such as creating and authoring engineering ABC children's books.

Programming LEGO Robotics

Preservice teachers embarked on a month long journey completely immersing themselves in basic programming of LEGO robotics. None of the participants had experienced programming before so it was a new experience for all involved. Preservice teachers were cautious and apprehensive about the notion of programming. During the first day of the course, students were required to build a LEGO robotic car using the LEGO Mindstorm robotic kit. Preservice teachers were introduced to a pictorial programming language called the Kontrol Zone where they literally programmed the LEGO cars using pictures on the computer screen. The goal of this classroom activity was to introduce the students in a gentle, supportive manner to programming LEGO robotics through various tasks such as "driving" the LEGO robotic car into a makeshift garage.

While I was involved in analyzing student journals, several aspects of computer programming surfaced that provided greater meaning to what students experienced when programming LEGOs. The following two categories were identified from the student journals: problem solving and communication.

Problem-solving

Developing problem-solving skills is essential as we move into the twenty-first century (Brown et al., 1992). The twenty-first century will be a complex and precarious world than what we live in today, especially in terms of science – which focuses on the future (Bentley, Ebert, & Ebert II, 2000). Learning how to problem-solve in the new century would involve various approaches, levels, and planes to make sense of a task that involved science principles.

Strategies for problem-solving such as guess and check, verbalization, and trial and error were the most commonly used and reported strategies that the preservice teachers implemented while programming LEGO robotics. Students worked in partners from the very beginning of this course and these problem-solving strategies were discussed being used repeatedly with their partners. Over time, preservice teachers became aware of using these specific problem-solving skills to complete the programming tasks. Eve was asked to reflect on her problem-solving strategies during programming exercises where she recognized and reported in a journal entry on two distinct strategies of her problem-solving approach. Eve responded,

> I learned that I need to talk out the solution as well as move in the same direction as what the car would be moving. We did this by using our fingers to be the car. If I was by myself, I probably would have not said anything out loud. I also would have had a harder time. I like talking out problems with another person.

Eve's reflection demonstrated her ability to recognize different strategies of problem-solving that were beneficial to completing the programming tasks. Brooklyn described a similar, yet more detailed account of her multiple problem-solving approaches,

> In this class we learn to problem solve and we learn this daily. It is extremely rare to walk into class, start programming, compile and download a program, run it, and have it work and do exactly what you are wanting to make it do. You have to problem solve. It is helpful that you have a partner to work with.

> Sometimes they come up with ideas that you would never think of. I have learned several different ways to problem solve. One way is to mentally plan out what you want your program to do. Another way, which I find it helpful to physically move the car and plan what it needs to do at all times. Another way is to talk your way through the program-say exactly what the car will do at each step-this, I have found very useful. I don't think I have ever problem solved so much in my life. I enjoy it, but you have to be able to deal with extreme frustrations sometimes you may feel there is nothing else you could try or do to make it work, but you know it can be done so it brings you back to one of the most important aspects of this class-*problem-solving*! [Italics added]

Brooklyn's reflection demonstrated how learners, if they possess more than one problem-solving strategy, were able to recognize when to use a particular strategy to guide them towards the best possible solution. The idea of multiple problem-solving strategies became important as the preservice teachers moved through the course. Students came to realize that they possessed a variety of problem-solving strategies that they could use when completing projects. Students also came to realize that they problem-solved differently when they worked alone than when they worked with a partner or group.

Joy examined the notion of problem-solving by titling a journal entry, "A Look At the Attitude's Role in Problem-Solving." Joy wrote in a journal entry, "I know that I am often more concerned about completing a project than I am about the process (problem-solving) and so set-backs cause me frustration because they delay my completion." Because Joy was able to reflect upon her problem-solving strategies, she was able to recognize that she was driven by the completion of a project, rather than the process it took to complete the project. Kris described problem solving as "something that you use in math" and came to the realization that problem-solving was a not only an approach that she needed to verbalize so that she was more successful at completing the task, but that problem-solving was also a transferable skill; not specific to the programming of LEGO robotics. In a journal entry, Kris described the following problem-solving situation,

> Jane and I have found that if we always say what we are thinking out loud, we can usually figure out where the other person is going wrong. I am starting to approach problems in my life with this strategy, as well. I find that sitting down and verbalizing my thought processes can really help me sort things out.

Other students chose to personally rank their problem-solving skills. In a journal entry, Jane shared the following reflection,

> I learned that my problem-solving skills were and are rather minimal and that it takes a much different thought process to do problem-solving versus the usual drill and practice way of doing things. I think that this is a great way to be learning and that I need to be opening my mind to new levels, sort of, so that this will not be overly overwhelming.

Many preservice teachers described the concept of problem-solving as being a process that, in the past, was given very little thought and attention. Although students were aware that they used problem-solved skills, they reported not ever being asked to describe *how* [italics added] they problem-solved. Brooklyn stated in her journal entry above, "I don't think I have ever problem-solved so much in my life." This idea appeared to be a common theme for most preservice teachers. The Toying With Technology course provided students with a supportive technology-rich environment conducive to problem solving. Students were able to freely attempt learning tasks using current problem-solving approaches while simultaneously adapting new strategies.

During computer programming exercises where students were required to problem-solve, I was able to observe their attempts at using trial and error. Students approached programming using lower level problem-solving strategies such as guess and check and trial and error. "Trial and error, an arbitrary search for solutions, is the least sophisticated form of scientific investigation" (Bentley, Ebert, & Ebert, 2000, p. 146). Furthermore, trial and error is a random search for patterns that will be used to solve problems or satisfy needs. While trial and error is certainly an important skill to use with very basic tasks such as trouble-shooting a simple computer error, it was not especially proficient for programming tasks. Students attempted programming tasks and if their initial approach did not work as anticipated, preservice teachers were observed "switching gears" without much discussion and attempting a different approach. I attributed students' abandonment of initial ideas and swift movement towards alternative solutions as common strategies for education majors. Many preservice teachers lacked specific training and authentic experiences when asked to use and draw upon higher-level problem-solving strategies.

As the Toying With Technology course progressed, cohort members were observed settling into more sophisticated problem-solving approaches. Trial and error was attempted using a more thoughtful approach. Mandy described an experience with trial and error that occurred towards the end of the Toying With Technology course. In the class WebCT environment Mandy posted the following reflection,

> We learn from each other, as students, from our past experiences. A lot of the work we do is trial and error. An example would be our egg drop project. We built a contraption and then tested the eggs; we made modifications to our machine to make it work more efficiently.

Learners can be taught to systematize trial and error so that it becomes a more efficient form of investigation. "The teacher can facilitate the process by asking questions and encouraging the use of record keeping" (Bentley, Ebert, & Ebert, 2000, p. 146). Preservice teachers were observed becoming more comfortable with their partner and together they developed problem-solving approaches specific to their particular team. Students reported an appreciation for being able to work in partners to help foster their problem-solving skills. In a journal entry, Jane articulated her thoughts about problem-solving individually opposed to problem solving with a partner,

> I problem solve differently with a partner versus me, by my lonesome, in that with a partner you are able to verbalize things and discuss various options that I may be thinking of and then comparing those thoughts with the opinions of my partners to see if I am headed in the right direction. If not, then talking about how we can get back on the right track i.e.-if I thought that we should use a different or certain pathway to putting the [robotic LEGO] car in the garage, then I would share my ideas with my partner and she could make suggestions for that and modify it as need be. Or [she] could give me a totally new suggestion for making the scenario better.

It was apparent that problem-solving became a very significant aspect of this course. Because of the significance surrounding problem-solving I purposefully asked students to write about their problem-solving strategies so that they became aware of how they approached problem-solving both individually and with a partner. Not only did the students report their problem-solving strategies as requested, they contributed many more details in their journals than I had originally requested. The preservice teachers chose to write freely and openly about problem-solving during various activities throughout the duration of the Toying With Technology course. It became clear to me that the vast majority of preservice teachers valued problem-solving as a transferable skill that could be used saliently during all classroom projects. Successful problem-solving during programming sessions allowed the students a sense of freedom and a sense of true accomplishment.

Problem-solving was frequently discussed in teacher education as a much needed and desired skill, yet teachers often did not provide students with authentic opportunities to *really* [italics added] experience the true process of problem-solving. Often times educators require that preservice teachers read about problem-solving, take methods courses to learn the importance of problem-solving for K-12 students, but educators simply do not provide preservice teachers with applications of authentic problem-solving tasks to accomplish and internalize this process.

In a WebCT entry posted towards the end of the semester, Beth provided an exceptional summarization of problem-solving, "We learn by doing instead of being instructed. We make mistakes, many of them, but when we get it, we have a better sense of understanding and a strong feeling of accomplishment." It was clear that communication was an important characteristic of problem-solving and that problem-solving rarely occurred without communication.

Communication

Communication is essentially transferring information from one person to another through verbal and nonverbal means (Bentley, Ebert, & Ebert, 2000). Moreover, communication is basic to the interactions of individuals and the sharing of ideas.

The concept of communication was repeated frequently in preservice teacher reflections. Many preservice teachers recognized the need to communicate clearly, purposefully, and frequently. During programming tasks, the many preservice teachers reported participating in communication frequently. In a WebCT posting, Morgan stated, "In this type of classroom there is a lot of communication between the students." The majority of cohort members stated that communication was essential to successful learning experiences and that communication was stronger in the company of a partner because together, the preservice teachers worked on building the relationship of trust and the ability to effectively communicate. Students reported the need to "talk out loud" to one another and to communicate in a descriptive manner using articulate language and clear meanings. Joy described how communication was established during computer programming tasks. In a journal entry Jane shared the following reflection,

> Communication was also easier when one of us was in control while the other listened. This could be seen when I was blindfolded. Because I had to rely entirely on her directions and not my sight; we were able to clear the obstacles rather easily, although the process was slow. When we communicate with one another we need to do so in a way that even if we were blind we would understand. Our words need to be descriptive and paint pictures. Clarifying and making sure one another understands during communication is also

> crucial. Talking through a problem rather than just thinking about if often gives new and valuable insights. It is best if we can teach ourselves through a variety of our senses, communication being one.

Communication was not viewed as merely a means to an end for the preservice teachers, but rather described and reflected upon as an integral component of being able to effectively convey ideas and possible solutions to problems that they encountered. Tiffany described communication in the sense of being successful, "The best success we had was communicating. We each voiced our opinion of how we should program and between the two of us we came close on the first try of the garage."

A Constructivist Framework for Learning

Although the Toying With Technology course was based on a constructivist framework for learning about science, technology, and engineering, the course also encompassed the learning theory of constructionism which supports constructing knowledge by building physical objects. Students in the Toying With Technology course were continually constructing physical objects as they were constructing new knowledge while connecting it to previous knowledge. The vast majority of students enjoyed and appreciated learning through a constructionist lens. Although constructionism was an important premise of the course, students reported the need to understand and internalize the constructivist learning theory. Because of this need, I did not dialogue about constructionism nor did I ask preservice teachers to report on this learning theory in any of the data sources.

At the beginning of the Toying With Technology course, preservice teachers were introduced to a constructivist framework for learning science, technology, and engineering. Students were asked to participate in virtual discussions and in-class reflections that related directly to constructivism. The majority of preservice teachers dialogued about constructivism frequently with each other both in (classroom dialogues) and out of class (virtual conversations).

The theme of A Constructivist Framework for Learning was used to describe the findings of how preservice teachers' developed their understandings of teaching and learning. The following six categories were identified during the data analysis process as contributing to this theme: Understanding a Constructivist Approach to Learning, Absence of Grading in a Constructivist Classroom, Constructivism as an Interactive Process, Self-Efficacy and Constructivism, Active Exploration of Materials in a Constructivist Environment, and Application of Engineering Principles in a Constructivist Classroom.

Understanding a Constructivist Approach to Learning

Throughout the Toying With Technology course, preservice teachers were introduced and engaged in a constructivist-based classroom. For many of the students, this was the first time that they had ever been exposed to constructivism in the context of a course that was based solely using this theory. Preservice teachers reported hearing about constructivism and attempted to explain constructivist concepts and ideas from a novice perspective. For example, although most preservice teachers were not able to provide sound descriptions about constructivism, they were able to generate basic ideas of a constructivist environment. For example, in WebCT, Mandy posted her thoughts on constructivism, "Constructivism is an approach to learning that holds people to actively construct or make their own knowledge and what they are learning is determined by the experience of the knower."

Several preservice teachers who provided brief descriptions about constructivism reported having limited experiences with this learning theory. From my own personal experience as a former preservice teacher in the same department, many of the instructors that encouraged discussions about constructivism in these education courses frequently provided narrow views about this learning theory. As reported by several preservice teachers, instructors often used key phrases such as, hands-on learning, active participation, and problem solving when they shared constructivist characteristics and qualities. Some students were able to provide more in-depth descriptions about constructivism. In a WebCT posting, Joy presented a detailed explanation on her ideas of constructivism,

> In a constructivist classroom, students are put in control of their own learning. The teacher acts primarily as a facilitator and directs learning by posting questions or presenting problems for the students to solve. In a constructivist approach, the students have the opportunity to construct their own meaning. They have the opportunity to draw on their past experiences, to evaluate different options and different information, pose questions, and compare and contrast different strategies of problem-solving.

Because all students came to the Toying With Technology course with different life experiences as well as educational backgrounds, some preservice teachers were able to provide a more elaborate description of constructivism than others. The students that had been exposed to constructivist practices described the concepts of constructivism in more detail than those students that had merely read about it or had limited exposure.

Absence of Grading in a Constructivist Classroom

Although absence of grading is not typically an expected occurrence of a constructivist-based classroom, being provided with authentic hands-on activities where the students direct and create there own learning is a more typical expected occurrence. Absence of grades in this constructivist-based classroom equated an environment that was conducive to unobstructed learning.

During the first month of the course, preservice teachers were purposely not assigned letter grades during the programming exercises to allow students the freedom to make mistakes without being penalized for their learning. Preservice teachers depicted mixed feelings regarding this approach. Some students harbored pessimistic views because up until this particular college course, preservice teachers had been assigned grades for work they completed in academic classes. Some of the girls found it incredibly stressful to be unaware of their academic progress.

Alison shared her thoughts on the absence of grading in a journal entry, "I am able to experiment and brainstorm because I am not afraid of trying new things and I believe by taking the pressure off, group members do not feel bad when they get the wrong answer."

The lack of grading became a positive experience for Alison. She worked beyond perceived constraints of course grades and focused more on the task at hand. Often, students were driven by grades so much that they lost focus on the task. Students were primarily focused on the end product instead of what or how they were learning throughout the process. Preservice teachers learned to relax and focus on problem-solving strategies to fix difficulties that they were experiencing during course projects while not worrying about a grade.

During a personal interview, Morgan revealed how the absence of letter grades for the LEGO robotic programming exercises had personally affected her. "Not getting a grade, I think, it was really tough. And I think it was tough for everyone. We were all like; I wonder what we are getting because everything our whole life is based on a grade." Morgan further stated,

> I think if you would have given us grades at first, it would have been easier for us, it would have been normal from us. But I think at first we put the pressure on ourselves about the grades because we [preservice teachers] always talked about it. Like, we wonder what our grade is, we wonder when we are going to get our grade. So even though you told us that we weren't going to get a grade for awhile, we always thought about it in our head. But I think after we got our first grade and after we realized what you wanted and what you were looking for, I don't think we were.....we didn't talk about it as much as we used to. I feel more relaxed because I know you were kind of working for us...more than before when you didn't tell us anything.

From the time students begin their educational experiences they are conditioned to receive letter grades for achievement. The reward for completing classroom assignments is generally a letter grade, which is assigned for assessment purposes. I was surprised that students felt threatened by not receiving a letter grade, which would have rewarded the progress of their work. However, many students felt threatened and upset by the absence of grades. They reported feelings of uneasiness because they did not formally know where they ranked in the course. It was only towards the end of the first month that students truly appreciated not being assigned grades to assess their learning. The students realized that learning required making mistakes and learning from those mistakes to be able to succeed at the tasks presented to them. "Failure" was a big part of the process of learning how to learn.

Constructivism as an Interactive Process

Preservice teachers described constructivism as an extremely interactive process where participants were allowed to work in teams or partners while creating their own learning interactively with each other. In a WebCT discussion posting, Morgan responded,

> …we learn more from each other than we do from a teacher. I think because we are all learning together and sometimes fumbling through the projects, we understand either what someone is thinking or why we are thinking that. Sometimes I think I feel more comfortable being "taught" by my peers than a teacher who sometimes can't understand what I am thinking.

Preservice teachers also communicated that the constructivist approach provided countless opportunities for hands-on learning to occur. Pam described hands-on learning in a journal entry, "Learning in a constructivist classroom is much like Toying With Technology because it is very hands-on and we work in groups most of the time." The following WebCT posting by Carmen illustrated her understanding of the hands-on aspect of constructivism. "It is constructivist in nature because we are always doing something with our hands, whether it be punching keys on the keyboard [to program the LEGO car], building LEGOS or designing the golf courses; this class is nothing but hands on." Another, more in depth description was provided by Karen in a WebCT posting when she interpreted her understanding of hands-on learning in a constructivist environment,

> The first thing I think of when I hear "constructivism" is the word construct. You build things! Constructivism is a *very* [italics added] hands- on approach, and the opposite of many of the classes that I'm taking now. It's not based on

a 50-minute lecture, you get information in a non-formal environment and instead of memorizing that information, you actually work with what you've learned and "build" things. You don't sit and read a textbook, add the information in short-term memory and then forget about it after a test. Working with the hands-on approach to learning, you recall information better and you are also able to retrieve information.

Students overwhelmingly associated and identified learning in a constructivist environment with a hands-on approach. I believed that the students associated the two concepts because this was the connection that they were taught in education courses and from required readings. Even if professors possessed minimal knowledge about constructivism, they were at least able to describe constructivism in terms of hands-on learning. The Toying With Technology course created a perfect context for hands-on learning to occur so preservice teachers associated this type of learning with constructivism. Preservice teachers connected theoretical knowledge to actual classroom experiences. Constructing knowledge through hands-on experiences as described by the preservice teachers in their definition of constructivism demonstrated active engagement with materials in learning tasks.

Active Exploration of Materials In a Constructivist Environment

The Toying With Technology course provided preservice teachers with an opportunity to construct a fully functioning miniature golf course using LEGO pieces with moving LEGO parts. The students expressed personal freedom when actively exploring materials and objects when constructing the golf course. In a Harry Potter miniature golf reflection paper, Kaitlyn described herself as actively exploring during the construction of her group's golf hole,

> We thought about how to use a hand while we explored other options. We also took into consideration the possibilities of having something come up from underneath the train to pop the ball up and out. This idea didn't work out well either. Finally, with all of us working together, and help from Steve [teaching assistant] we came up with the idea of a "windmill" type of propeller. This worked out well to get the ball out of the train. The only other problem we faced with this is a bump sensor triggered this "windmill" and sometimes the train did not go straight, so it did not hit the sensor, so the ball did not move. During our course we had to continue to line the train up perfectly in order for the bump sensor to trigger the "windmill."

Kaitlyn provided a very articulated description on how she and her group members explored and manipulated the materials that they used to construct a miniature LEGO golf course hole. Kaitlyn's group was creating authentic knowledge while connecting it to previous knowledge. Students produced new knowledge of creating moving parts on their LEGO golf hole with previous knowledge of basic programming that they learned during the first month of the course. In addition, the group was able to synthesize knowledge about miniature golf courses when creating their LEGO golf hole. All students reported previously playing on miniature golf courses so the students were able to bring this previous knowledge and connect it with the creation of their knew LEGO robotic golf hole. Preservice teachers also applied previous knowledge of actual engineering principles such as designing, creating, and testing when they created their LEGO golf holes.

Application of Engineering Principles in a Constructivist Classroom

The application of engineering principles was demonstrated during the construction phase using the idea of simple machines. The following quote from a journal entry indicated how engineering principles were applied. Kaitlyn reported her application of engineering principles in the following way,

> We used two sensors, a light sensor and a bump sensor. Our light sensor was used in the beginning of the hole. As the light sensor picked up the ball falling in the back of the train, after being putted up the incline, then the train would move forward. Our second sensor was in the wall across the track where we had installed the bump sensor. Once the train hit the bump sensor in the wall a "windmill" would spin and knock the ball off the train. After the "windmill" knocked the ball off the train then the golfer had to golf from where the ball landed.

This example was representative of how preservice teachers actively drew upon their knowledge of engineering principles (simple machines) by creating the incline, which was used to negotiate the obstacle constructed in this particular LEGO golf hole. This team was able to synthesis their knowledge of simple machines as objects that makes work easier by incorporating an incline into their design as a way that assisted the golfer to reach the LEGO golf hole. Similarly, the windmill (wheel) that the team incorporated was another simple machine to aid the golfer. Students were using previous learned knowledge about simple machines in order to construct new knowledge about the application of simple machines in the context of creating a LEGO golf hole.

Self-Efficacy and Constructivism

Throughout the semester, preservice teachers struggled with learning in an engineering course that implemented a constructivist framework for learning science, technology, and engineering. Early in the semester, several students reflected in personal journal entries that they did not like learning in a constructivist classroom. Morgan explained to me during a personal interview that she did not particularly care for learning from a constructivist approach. Morgan shared her feelings on constructivism,

> When I was doing it I hated it because I had never been taught like that. Even when I came to college it was a lecture, go home study and take the test. But I've realized that since I've taken it, [the Toying With Technology course] I teach more like that than I think I ever would have.

While Morgan shared feelings of dislike, other preservice teachers reported feelings of being overwhelmed and very frustrated. Although preservice teachers described that most of their frustrations occurred during the programming exercises, it was the constructivist approach to teaching that created those feelings of frustration for the students. I led the students into programming exercises by providing a secure, supportive environment. However, what I did not provide the preservice teachers was a "hand holding" experience.

Brooklyn described feelings of frustration in her journal, "[I learned] don't give up or get frustrated as you'll figure it out sometime. Don't rush, take your time to think out what you're going to do." Although Brooklyn experienced certain levels of frustration during the Toying With Technology course, Brooklyn also recognized that she must work past her frustrations in order to move forward in the course. Other students reported similar experiences where they too must learn to control their feelings of frustration or it will take over and they will be unable to move past this feeling.

In the Toying With Technology course, preservice teachers began to realize they would not receive help in the form of answers. In the classroom, I emphasized the constructivist approach of teaching and allowed a certain level of frustration to occur. For example, Eve shared the following experience related to course frustrations,

> One interesting thing that happened on Thursday was that we discovered how to use the bump sensor. I was very frustrated with it and almost had to leave the room, but we got a clue from Steve [undergraduate teaching assistant] and were able to figure it out and move on.

By taking a step back and obtaining some external assistance with her thinking strategies, Eve was able to reflect and work past her frustration. She was then able to effectively move on to the next task. Many times getting past the frustration required the students to actually physically leave the room in order to distance themselves from their immediate annoyances.

Many preservice teachers reported on the negativity of frustrations, however, Joy described optimistic thoughts about frustration in her personal journal. Joy shared the following reflection,

> Although a constructivist classroom can end up leaving students confused and frustrated, in the end, students who work through difficult tasks actually learn and remember more because it has meaning for them. Constructivist approaches can be much harder but also much more rewarding.

Joy reflected on frustration as being almost an integral element of a constructivist classroom. When students experienced the frustrations and worked through the difficult tasks that were presented in this type of classroom students actually created more meaningful experiences for themselves. Although feelings of frustration occurred and were reported frequently, preservice teachers reported experiencing other, more positive feelings while participating in the Toying With Technology course as well.

The feeling of confidence developed as an additional emotion that preservice teachers articulated. Students described confidence in terms of feeling more confident about their work in the class. For example, when a Kaitlyn described a LEGO robotic programming experience in her journal, she wrote, "Seeing our car do exactly what we wanted it to do was fun and helped strengthen our confidence in programming." Other preservice teachers reported confidence in terms of their skills. In a WebCT posting, Eve shared her ideas about confidence,

> This is the first class that has been a constructivist classroom and I think that I have learned a lot so far in this class. I feel more confident about my skills in technology and confident when talking about engineering.

Preservice teachers did not speak about confidence until the end of the first month of the course when they finished their basic LEGO programming experiences. Once students were more comfortable with their programming skills, they began to report on the confidence they gained while learning how to program. Preservice teachers also reported on their confidence levels when they were required to work in outreach experiences with K-12 students to assist with basic programming experiences. Cohort students reported having increased confidence after teaching the basic programming exercises to K-12 students. This time period became a pivotal turning point for preservice teachers. When preservice teachers successfully instructed other individuals during programming experiences their confidence levels skyrocketed.

Towards the end of the course, preservice teachers reported feelings of pride. Students felt that the hard work they had invested in the course finally paid off. Students experienced many more successes towards the end of the course because they finally became comfortable with the programming aspect of the course and became accustomed to working in a constructivist environment. In a detailed WebCT posting, Joy provided the following insight,

> On a little side note, I think there is so much power behind the constructivist approach because it gives students pride and ownership in their own leaning. When I think of the things I have gained in our classroom they are things I have learned by experiencing our projects, and not things I have been told to write in a notebook.

Brooklyn responds to Joy in WebCT with this posting,

> I also agree with Joy, one reason I feel that way is because in TWT [Toying With Technology] I feel like I have pride and ownership of my finished products. (Even though sometimes they don't always work as planned!) But when students put that much time and effort into something like this, their work means a lot to them. I think when using a constructivist approach it makes them feel better about themselves; better than if they take a written test and do good, because they have something 'bigger' to show how hard they worked.

Preservice teachers had a difficult time transitioning into a classroom that employed a constructivist framework for learning science, technology, and engineering. For many students, it was the first "real" constructivist classroom that they had ever participated in without the typical constraints that confronted many traditional classrooms. At the beginning of the semester, students discussed the absence of grades as both a positive and a negative experience. However, at the end of the first month, students appreciated not being penalized for learning. Programming LEGO robotics proved to be a difficult task for many students and coupled with the constructivist environment students reported feelings of being challenged and frustrated. I had hoped that students would rise above the fear of the constructivist classroom recognize all of the advantages that this type of approach to learning had to offer. I directly attributed students frustrations with the constructivist approach as having had limited experience with this type of learning methodology.

Applying Engineering Ideas and Concepts in K-12 Classrooms

The theme of Applying Engineering Ideas and Concepts in K-12 Classrooms was used to describe the findings of preservice teachers and their understandings of how they described the application of engineering ideas and concepts in K-12 classroom experiences. The process in which preservice teachers applied their learning with engineering ideas and concepts was undoubtedly one of the most important aspects of the Toying With Technology course.

The following two main categories were identified during the data analysis process as contributing to the theme of Applying Engineering Ideas and Concepts in K-12 Classrooms: Teaching Engineering in Field Experiences and a Desire to Implement Engineering in K-12 Experiences.

Although my research primarily included collecting data from preservice teacher participants for a single semester, I was provided with the opportunity to gather data from the preservice teachers one year later. The girls would have completed their science methods course by that time and I thought it would be interesting to provide the students with a post engineering questionnaire (See Appendix C) to see if they had implemented any of the knowledge and activities from the Toying With Technology course. I sent a questionnaire that contained eleven questions through e-mail to the preservice teachers. Students wrote responses to the questions and e-mailed me their reflections. Students reported on how they had used ideas from the Toying With Technology in practicum experiences.

Teaching Engineering in Field Experiences

One year after finishing the Toying With Technology course, several preservice teachers reported that they were able to actually implement various knowledge constructs learned in the course. Students reported replicating the following activities: polymer lesson, bridges, oobleck, shrinky dinks, asphalt cookies, ABC books, and toothpaste. Alison was able to use the toothpaste activity as she explained through an e-mail response, "I used the toothpaste lesson but just in a lesson plan that I am incorporating into a health unit."

Although Alison described using the toothpaste activity that she learned in the Toying With Technology course in a future field experience, it is apparent that she did not use this particular activity to help students understand engineering. When Alison participated in the toothpaste activity in the Toying With Technology course, she did so to learn about chemical engineering. I perceived Alison's incorporation of this particular lesson into a health unit to signify that Alison identified making toothpaste as a fun activity rather than as an activity that could have been used to introduce K-12 students to engineering. However, Eve reported a different outcome in terms of implementing learned knowledge constructs in engineering. In an e-mail response, Eve provided a detailed description of how she incorporated what she learned in the Toying With Technology course into a practicum field experience,

> I encourage more students who are interested in how things work to explore the things that they wonder about. For example in my practicum experience there is a girl who enjoys drawing and designing buildings and I went to the library and got a few architecture and engineering books. I also feel more knowledgeable about engineering and feel comfortable talking about it. I feel that this will benefit me in the future because I want to have a science (as well as other subjects) class that comes up with questions which shapes the curriculum that I choose to teach. I know that if one child's question had something to do with engineering before I took TWT, I wouldn't even have known where to start. Now I feel knowledgeable enough about engineering to provide an environment where my students can learn. I also have shared our ABC books with students in my classroom because the students in my class wanted to create their own ABC books and I thought our book [an ABC engineering book created by Eve in the Toying With Technology course] was an excellent example of an ABC book and topic.

Eve appeared to possess a deeper understanding of what she learned in the Toying With Technology course. She described in detail several experiences where she took what she learned in the course and directly applied it in a field experience. Eve also used her knowledge of engineering and applied it in the context of engineering which is how she learned it in the Toying With Technology course. When Eve described the ABC book project, it appeared as if she was using the ABC engineering book that she created while a student as an example but not in the context of having her practicum students create their own engineering ABC books. From the language that Eve used to describe this phenomenon, it appeared as if Eve was using her ABC book merely as an example of an ABC book, not an example of an *engineering* [italics added] ABC book. Eve, like Alison replicated projects from the Toying With Technology course that they perceived as fun and incorporated them in field experiences but not to in the context of engineering.

Jane described in her e-mail response how she used her knowledge of engineering in a particular field experience,

> In the first days of my practicum this semester I was placed with the science teacher and she was in the midst of a unit on bridges and the 4th graders were working on creating their own bridges with connex [K'NEX ®.] I thought it was awesome as that was the subject cover in our ABC book [engineering ABC book created by Jane in the Toying With Technology course] and therefore, I felt very knowledgeable about this so I offered suggestions to this teacher of the extensions available at my college and suggested that the people come in for a demonstration of the bridge they can crawl through. Unfortunately, I did not see the unit play out in its entirety because I was switched into another classroom. I thought it was great though to see the students' excitement to learn more about bridges and that what we did in Toying With Technology did have a part in the classroom. I wished I could have introduced the idea of bridge poetry [an activity she participated in during the Toying With Technology course] to them as well.

Some students reported being able to easily replicate activities in their field experiences however, most preservice teachers did not provide enough detail in their responses to draw the conclusion of whether or not they were teaching about engineering when they introduced and used these activities with children. By examining the data, I was able to hypothesize that students mainly replicated activities that were perceived as fun. Students were not intentionally replicating projects to introduce engineering principles and concepts but rather to spark the interest of a child with a hands-on entertaining activity.

Desire to Implement Engineering in K-12 Experiences

While the theme Desire to Implement Engineering in K-12 Experiences was not broadly expressed across the data, it was however a significant finding. I defined this significant finding in terms of long-term retention for understanding of basic science concepts that they learned and participated in while a student in the Toying With Technology course. This was finding was pivotal in that students remembered and used what they learned in practicum field experiences. The learning that occurred in the course had made a lasting impression on how they viewed science and technology.

Preservice teachers reported being excited and more than willing to introduce engineering into future K-12 field experiences. If students had not already done so, they reported that they had been unable at this particular time to implement engineering ideas and concepts. In an e-mail response, Carmen described why she has been unable to replicate engineering activities in current field experiences, "I actually haven't had many opportunities quite yet to replicate some of the activities that we did during our course. This does not mean that I do not plan on it, the opportunity just has not [sic] arisen."

I attributed the lack of actual implementation of engineering activities into K-12 field experiences as two-fold. First of all, I believe that students were provided with limited opportunities to incorporate engineering activities. Even though the curriculum lent itself to engineering concepts and principles, many K-12 educators were unaware and uniformed about the field of engineering. Furthermore, many educators were unaware that engineering is the application of science and technology and that current curriculum that is incorporated in the K-12 classroom contained many opportunities to apply science and technology using engineering as a context.

Secondly, I contended that preservice teachers were still apprehensive about incorporating engineering into field experiences. Students appeared hesitant when introducing anything that deviated from the "norm." Because preservice teachers were still working under classroom teacher mentors at that point in their educational careers, it might have been uncomfortable for the preservice teachers to approach their mentors to suggest a different approach to both teaching and learning.

Summary

During the Toying With Technology course preservice teachers were provided with a "taste" of how to incorporate science and technology into K-12 education using engineering as a context. However, limited experiences may not have been enough to sustain what the students learned. I ascertained that preservice teachers needed much more than a single, contained experience if they were expected to successfully implement engineering as a context to teach both science and technology.

Students reported feelings of frustration, pride, and finally confidence in terms of learning the programming language "Not quite C" and applying the language when building and programming LEGO robotics. Students appreciated the opportunity to participate in learning about the field of engineering which most reported as being something only people good in math and science learned about.

Problem-solving was a major catalyst in the Toying With technology classroom. Many students realized that they possessed certain problem-solving strategies but were unaware of their problem-solving skills until they were expected to verbalize and write about how they approached tasks using their problem-solving strategies. Many students reported that problem-solving with a partner required much different approaches than having to problem-solve alone. Students appreciated having another person to communicate with when completing difficult tasked that required higher-level problem-solving.

Communication was described as being an important aspect of problem-solving as well as contributing to a successful constructivist classroom. Preservice teachers were expected to communicate with one another in order to convey ideas to complete various short and long-term tasks. The constructivist approach to teaching and learned proved to be a difficult transition from the students' normal learning experiences. Students were accustomed to learning in more traditional manners that lacked group participation, problem-solving, and communication.

In practicum field experiences, preservice teachers actually implemented information and activities that hey had learned in the Toying With Technology course. Students created fun, authentic experiences for elementary students but the experiences were rarely in the context that taught elementary students about engineering. Many cohort members reported the desire to implement ideas that they had learned in the Toying With Technology course but lacked the opportunities to do so. Finally, students reported an overall appreciation for what they had learned and expressed the desire to implement engineering into future K-12 classroom experiences provided that opportunities were available.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

The purpose of this descriptive case study was to describe the experiences and reactions of a cohort of education preservice teachers enrolled in an engineering course titled Toying With Technology and to gain a deeper understanding of how preservice teachers described and reported learning in an engineering course that used a constructivist framework to learning science, technology, and engineering.

The participants in this case study consisted of twenty-two female preservice teachers. The students were classified as the following majors: nineteen elementary education majors, two early childhood majors, and one secondary education biology major.

Data for this research study were collected from the following six sources: classroom observations and interactions, field observations and notes, reflective journals, WebCT postings, project artifacts, and personal interviews. The data analysis process was based on a descriptive framework. The data were initially sorted according to data sources and then by the following time periods: early semester, mid semester, late semester, and post semester. Data were coded by highlighting key words and phrases. Data were then entered into a Microsoft Excel spreadsheet that was structured around the data sources and data questions within these sources. Finally, themes were then identified using the Microsoft Excel spreadsheets.

In this chapter I would like to revisit these stories framed by the research questions that guided this descriptive case study. During this process, I will revisit selective data in

Chapter IV and also report on student examples and reactions that relate directly to the research questions. The following four research questions were examined in this study:

1. How do preservice teachers' perceptions develop while participating in a course featuring engineering principles?
2. As a result of this engineering course, how does the use of a constructivist approach in teaching and learning effect preservice teachers' perceptions of science and technology?
3. How do preservice teachers describe personal experiences with engineering based projects?
4. How do preservice teachers describe implementation of what they have learned about science, technology, and engineering?

Research Question 1: How do preservice teachers' perceptions develop while participating in a course featuring engineering principles?

During the Toying With Technology course, preservice teachers learned about engineering principles through various computer programming exercises and engineering based activities. Students were also introduced to science and technology principles using engineering as a context.

At the beginning of the Toying With Technology course, most preservice teachers possessed very rudimentary ideas about engineering. Many students were only able to report specific fields of engineering and basic characteristics associated with this field. As the students moved into programming LEGO robotics using the "Not Quite C" computer programming language, students mentioned feeling frustrated and intimidated. None of the preservice teachers had never experienced programming before and this inexperience seemed to contribute to their negative feelings associated with this activity. As the course progressed, the majority of preservice teachers became more comfortable and confident with computer programming, and appeared to attain higher levels of problem-solving.

During programming exercises, the vast majority students became metacognitively aware of their problem-solving strategies. Most preservice teachers reported possessing problem-solving skills not typical of traditional science and technology courses. Throughout the Toying With Technology course students were required to problem-solve at more advanced levels. The students built upon their problem- solving strategies and reevaluated those strategies when the strategies were unsuccessful. Most preservice teachers reported that working with a partner was a significant part of their success when problem-solving. As the preservice teachers worked to solve problems in this course, the girls openly discussed the importance of verbalizing and sharing their ideas with a partner.

Many preservice teachers had a difficult time making connections with K-12 curriculum and engineering principles. As future teachers, several students questioned why teaching engineering should take precedence over teaching about other professions. Students found it difficult to understand that I was teaching them how to use engineering as a context to teach science and technology rather than teaching them about the field and profession of engineering. As the semester progressed, preservice teachers were able to understand that engineering was used as a framework to incorporate the teaching of both science and technology.

Research Question 2: As a result of this engineering course, how does the use of a constructivist approach in teaching and learning effect preservice teachers' perceptions of science and technology?

Preservice teachers began the Toying With Technology course with narrow views about constructivism. During the course, constructivism quickly became the culture of the Toying With Technology class and set the stage for future learning experiences. The formation of partnerships was a critical aspect of this constructivist classroom. Students overwhelmingly reported that being able to work with partners and groups was a positive experience and extremely important in their success with course projects. Many students believed that they would not have been as successful learning and crafting projects if left to do so independently. Partnerships were described as comfortable relationships where partners displayed feelings of encouragement and were provided with an environment where each member felt that it was ok to "fail." Brooklyn wrote in her journal, "Two brains are better than one." In a WebCT posting, Mandy provided a detailed description about groups,

> If we didn't work in groups I think I would have gone insane. There were times where I became very frustrated and didn't know what to do. But, because I had other group members that had different ideas than I and we worked through the frustration and completed the project. We all had different ideas and came up with one finished product. I enjoyed working with others because it really made me work cooperatively. I know I would not have learned as much if I would have worked on my own. Like I said earlier, I would have gotten frustrated and just given up. I learned so much from my

> classmates and from myself. I know I have said this before but I will say it again, you learn more when you have to teach someone else, and that is how this class is. We are always teaching each other.

The findings of this study illustrated that when learning about science and technology, students believed that they learned better with partners in an interactive, hands-on environment. The active explorative discourse provided the opportunity for preservice teachers to develop self-efficacy in their thinking about teaching the content areas of science and technology. As a result, students progressed beyond feelings of frustration, towards confidence and finally as the course commenced, pride.

Two years following the course, a videotaped documentary depicted preservice teachers discussing the impact of the Toying With Technology course. The entire premise of the Toying With Technology course was based on the belief that students were allowed the opportunity to think outside the box. Preservice teachers were not provided with traditional "means to an end" assignments to learn the content of the course. Students were provided with general guidelines based on engineering and science principles which led the students to think about what approach best served their individual learning needs to solve the problems set forth before them. The notion of "thinking outside of the box" was evident even two years beyond the time the girls completed the Toying With Technology course. A movie, which was created by the students, summarized the accomplishments of the preservice teachers during the three years that they participated as a cohort. Chelsey reflected on her Toying With Technology experiences during this video,

> I didn't think I would ever be able to do a lot of the stuff we were doing in there. It was a really great way to learn [problem-solving] skills and new information that I had even thought of putting in a classroom in that way and it me think outside of my box of the way I would normally teach.

Research Question 3: How do preservice teachers describe personal experiences with engineering based projects?

As a result of the engineering based projects, students described their personal experiences as fun, creative, engaging, as well as frustrating. Students preferred activities that were highly engaging and that allowed them to cooperate, communicate, and problem-solve with partners. Preservice teachers used the words fun, creative, and engaging, to describe projects that created real-world connections such as the design and development of a Harry Potter miniature golf course, making asphalt cookies, and authoring ABC engineering children's books. During the class, students were the most positive about long-term, authentic projects and did not want to commence their learning during activities such as the Harry Potter miniature golf course.

One specific project that the preservice teachers participated in during the course was the creation of a children's ABC engineering book (See Appendix H). Students were required to research a specific field of engineering and design an ABC book for children. The preservice teachers created the most wonderful books. The effort that each student put into the books was apparent by the quality and professionalism of the books. One team of students approached a group member's mother, who was a professional illustrator by trade, to illustrate their book. This book already had a professional flare to it, which provided me with the idea to contact the Devon, the engineering professor associated with the Toying With Technology course.

After the course had commenced, I contacted Devon to show him the finished products. I wanted to gain his opinion about the books to see if he thought if we should contact a publisher to publish and disperse these books. Currently, children's literature lacks books that introduce and discuss engineering; there really was a need for books like the examples that the students created. A publisher of science and engineering textbooks was located and approached with the idea of the ABC engineering books. The publisher was cautious, yet accepting of the books but relayed concerns of reaching an appropriate audience for the books. He agreed to design a protocol of one of the engineering books to showcase at engineering conferences. The publisher received a lot of unexpected positive response about the ABC book.

The publisher agreed to publish the book in addition to publishing a color book of this engineering book. The engineering college at the institution where this study was conducted agreed to purchase enough of the ABC engineering books to distribute one copy to each first grade classroom in this particular state. The engineering college also agreed to purchase enough color books to provide each first grade student a color book.

Research Question 4: How do preservice teachers describe implementation of what they have learned about science, technology, and engineering?

Approximately one year after the preservice teachers completed the Toying With Technology course, Chelsey, one of the preservice teachers, unexpectedly contacted me. According to Chelsey, she and several other cohort preservice teachers were presented with an opportunity to student teach in Australia. She stated that approximately four or five other preservice teachers would be interested in the opportunity in student teaching overseas. Chelsey continued to reminisce about the projects that the cohort preservice teachers participated in while students in the course.

I probed Chelsey to discuss what specific aspects of the Toying With Technology course that she and the other students were interested in replicating. Chelsey explained that she and the other students were interested in replicating the LEGO robotics because "that was the part that we enjoyed the most . . .Yeah when we did the cars and the different tracks and the program that we used."

Chelsey was initially concerned with funding in order to obtain the necessary LEGO kits that the preservice teachers would need to obtain in order to implement the LEGO experience for the K-12 students in Australia. She stated that she and other preservice teacher were interested in learning more about grants. "We've been researching grants, and I'm still hitting walls with these things 'cause you know, finding a way to make it work is a problem."

I questioned Chelsey as to why she was interested in introducing the LEGO robotics to the Australian children. She stated that she and the other preservice teachers could assist the kids with their problem solving skills using the LEGO robotics. "I was thinking, we were thinking, that in math you could use it, or any aspect of your classroom that you're in that you use problem solving skills." Chelsey went on to state that by using problem solving skills in the Toying With Technology course; "We learned how to program these cars, and this was a foreign language to almost to us. I mean it is a foreign language and we were able to sit there and understand that."

I probed Chelsey further to see if there was anything else pertinent that she wanted to tell me about in describing her ambitious undertaking of creating an opportunity to purchase and use the LEGO robotics in Australia. I asked her if she considered incorporating the LEGO robotics in other subject areas other than math that she had previously explained. Chelsey explained that she was thinking of incorporating LEGOs into reading.

> I was thinking that it would be really neat for the children to illustrate the stories using robotics. Like if they made a map of the story or the setting and using the cards to go in and out of the setting or making the cars as the characters or the stories. I just think that it can be in anything that you do. Its' not even a stretch. Like, I don't' feel like, sometimes I felt like I having to stretch to put certain technology into my classroom . . . with the cars, I just felt like there was a lot of opportunities. You wouldn't use it every day because it would take so long, you know. But after the kids understood how to use them (the cars) after you taught them how to use them (the cars). But after the kids understood how to use them after you taught them how to use them, I think it would be great to have them use their imaginations like that.

This was an example of a preservice teacher internalizing concepts that she learned in the Toying With Technology course and extending her own personal knowledge and skills while applying this knowledge when faced new teaching experiences. As a practitioner, this is the outcome that we hope for our students. Not only did Chelsey learn from her experience in the Toying With Technology course, she now wanted to teach incorporating ideas that she learned. Chelsey was able to apply what she learned from the Toying With Technology course. To me, this demonstrated that she internalized the learning that occurred within the classroom and showed enough confidence and understanding of the principles and applications of technology, science, and engineering to meaningfully incorporate them into other curricular areas. In my experience with working with preservice teachers having a student take the knowledge and skills that were learned in the college classroom developing newer innovations based upon concepts is a rare occurrence. Not only was Chelsey thinking about her future teaching, she was examining ways to build upon what she learned in the Toying With Technology course.

Auxiliary Findings

Preservice Teachers Identified as a Cohort

Although I never intended to research the preservice teachers as a cohort, the theme of "cohortness" developed. This theme did not address a specific research question but clearly a story that was important to the students.

Preservice teachers discussed participation in the cohort as an overwhelmingly positive experience. Reflections that contained words and phrases such as fun, support, resource, lifetime friends, working towards a common goal, and a tight knit group of friends were consistently represented and reflected upon in the students' WebCT postings.

The role of being a member of a cohort went well beyond the academic aspect, being a member of a cohort permeated the students' personal lives as well. Students reported spending time with members of the cohort outside of school as well. In a WebCT posting Morgan reflected,

> To be in a cohort is more than just a simple answer. For our cohort, it started as taking classes together and all having an interest in education. But after we

got to know each other it became more of a network of friendship, guidance, listening, and advising. We all have the education major in common and we talk to each other about our problems, the positive and negatives that happen in our day dealing with students, classes, and other various things that have to do with education. Not only do we talk about education but also we have grown to know each other as individuals so we don't just talk about our classes anymore, but our personal lives. We are there for each other in the academic sense but also we are there as a support system for one another.

Morgan's description was evident and representative of many of the cohort member's feelings. Students began participation as a member of an academic cohort but commenced the experience developing and maintaining wonderful friendships that the preservice teachers reported as being able to "last a lifetime."

Being a member of the cohort was far more advantageous than most initially could have ever imagined. Preservice teachers shared reflections of appreciation of having access to a support system, a sense of belonging, and being able to share ideas with others as the most important aspects of participating in the cohort. In a WebCT posting, Emily shared her thoughts on how much the cohort members make use of each other as resources, "Everyone has different opinions about teaching and we can share and help one another to be the best possible teachers. As they say, two heads are betters than one, or in our case twenty-two heads are better than one."

The cohort was reported as a "sisterhood" where all members shared and participated in specific roles. Kris posted the following WebCT entry, "Our role is to be in class, participate, work with each other, and help each other. We are accountable not only to our teachers but also to the others in our cohort." During a personal interview, Morgan provided a detailed account about roles of cohort members,

> Every person in the cohort plays every role at different times in our group. There are leading roles, (if someone understands something they explain), following roles, (being explained to), helping roles, advising roles, listening roles, and probably others that I just cannot think of right now. The roles in the cohort are used everyday by every person possibly at the same time-no one is assigned a specific role.

The roles that each student participated in during the cohort have comparable similarities to roles that family members would share. This notion was not surprising because the girls reported feeling part of a cohesive "family" unit. Preservice teachers appreciated the closeness of their group and attributed it to more successful educational experiences. In a WebCT posting, Tiffany supported cohort roles by stating, "Our roles are important in the growth of our cohort." Roles were attributed as being more than something that students informally participated in but rather viewed as a growth experience that was vital to the development and organization of the cohort.

Preservice teachers described relationships with professors as special. Students truly believed that professors had a vested interest in their learning, which in turn led to more accountability on the part of the student. However, students reported feeling the need to be held accountable as a standard set forth by themselves and the other cohort members. In a WebCT posting, Emily reflected on how relationships with professors were different when you were a member of a cohort,

> It was also great being able to get to travel with them [professors] to Tennessee [for a conference] where we actually "hung out" with the professors. It was great to see Dr. Smith and Dr. Thornton line dancing with everyone. We had a lot of fun and I thought these experiences don't just see my professors as educators but as people who like to go out and have fun too. This is also a great way for the professors to get to know more about you too. Not only will they know how you perform on class activities, but on a different level and be able to connect with them on a variety of things. I feel it is very important to feel comfortable knowing professors and I know that if I was having trouble with anything, I could go to any one of them for advise or help.

Cohort members appreciated having the professors view them as more than just students. Similarly, the preservice teachers viewed the professors as people who led and shared their personal lives beyond the academic walls. In a sense, this made the professors more "real" to the students.

Participating in the cohort was not always described as a positive experience. Preservice teachers described limiting experiences as well. Students reported that working with the same group of individuals was at times a disadvantage. Madison described a disadvantage in an e-mail response, "A disadvantage is being around the same people all the time. It gets to be a little tiresome and sometimes you just want to get away from them." Preservice teachers also described instances where the cohort became involved in cliques. In an e-mail response, Joy described less desirable cohort aspects,

> One negative is that a cohort can become a clique if we are not careful. It also can exclude certain members. We may also be limiting ourselves by not hearing others' [education majors not involved in the cohort] points of view outside of our cohort. Since we all have the same teaching [experience] it would be easy for us to miss other perspectives.

Cohort members described having a desire to hear more outside perspectives. In an e-mail response, Emily shared what she perceived was a disadvantage of being in a cohort, "The only disadvantage I can think of is that we don't get to meet a lot of other people. This year we have other people mixed in our education classes and we get to hear other perspectives, even male ones!" Limiting views became a diminutive aspect of the cohort experience. Preservice teachers also reported preservice teachers not associated with the cohort as expressing feelings of negativity towards the cohort. Many cohort members reported that they received the message from "outsiders" that they received preferential treatment and were very stuck up. Alison stated, "I now see how others respond towards us in a kind of negative way as if we get special treatment."

One year after completing the Toying With Technology course, students were able to report additional positive cohort experiences. Brooklyn described the following experience in an e-mail response, "You build a good connection of people to use in the future for ideas." Preservice teachers further described feelings of belonging, cohesiveness, teamwork, and sharing of ideas. Finally, students felt that being a member of the cohort provided them with more field experiences that led to feeling better prepared to enter the teaching profession. Kaitlyn shared her feelings of preparedness in an e-mail,

> I feel blessed to be in this cohort. I think we have gotten a stellar education being part of the cohort experience. I don't [just] feel ready to student teach, I feel like I'm ready for my own classroom! It is all around just a great thing.

To celebrate three years worth of cohort accomplishments, cohort members prepared a PowerPoint slideshow called "What We Say About Each Other" that depicted pictures of all twenty-two preservice teachers (See Appendix I). The PowerPoint presentation included individual slides for all twenty-two students that contained their picture. Preservice teachers each wrote one positive comment that surrounded the individual's picture. Words and phrases such as intelligent, great asset to any school, funny, inquisitive, willing to lend a helping hand, involved, will be a great teacher, and creative were used to describe each other. Cohort members, still remembering positive experiences associated with the Toying With Technology course, wrote comments about the course on three different preservice teachers' slides. The following were recorded comments were recorded on the slides: "Engineering A to Z book published", "Best Harry Potter Golf Course", and "Engineering A to Z book published." Toying With Technology was the only course that students participated in during their three years as a cohort that was depicted on the PowerPoint slides. As stated by Alison in an e-mail response, "This course [Toying With Technology] made me finally understand the key phrase that knowledge is power and that what you don't know does hurt your learning."

Recommendations & Future Research

Results from this exploratory study indicate that further research is needed to develop courses similar to Toying With Technology in order to improve preservice teacher preparation in the areas of science and technology. Institutions of higher education are less likely to incorporate teacher preparation courses embedded in engineering programs, however this study opened the door for innovations to develop and for teacher preparation programs to create courses similar to Toying With Technology. Interdisciplinary relationships are crucial for the development of successful partnerships between education and engineering. Engineering educators provide the content expertise while teacher educators provide the methodology and pedagogy for teaching and learning. The lines between university departments need to be removed to allow for collaboration, joint efforts and co-teaching for similar courses in science and technology. There are few preservice teacher programs that employ engineering as a context to teach science and technology principles. The Toying With Technology course has shown promise for preparing future teachers in the areas of science and technology.

Future work should combine both qualitative and quantitative research techniques to examine the effects of integration of engineering and education courses on preservice teachers. These studies should include research on the introductory year's experiences of students from these programs.

Recommendations From Preservice Teachers

Several preservice teachers offered recommendations for teacher preparation programs. Students suggested that teacher education programs should examine science methods courses in terms of how they introduce strategies for teaching K-6 science to preservice teachers. Several preservice teachers expressed a grave concern that science methods courses do nothing more than provide theories of how children learn and do little in the way of teaching future teachers how to "do" science. Some students believed that participating in only one science course during their undergraduate teacher education program limited their opportunities to learn how to teach science.

The current situation in teacher education programs for preparing preservice teacher is viewed using a minimalist approach in the areas of science and technology. This notion is mirrored in K-6 education's prioritization of science and technology. As one example, a student expressed her concern during a personal interview,

> Well actually my classroom is different than any of the other ones because their normal teacher left right after Christmas break, so they got a new one [teacher] and they are really far behind in reading so the principal wants them to focus on reading and if they don't get to math and science they don't get to math and science.

From this particular student's reflection, it is evident that elementary school teachers are sent the message that science and math are secondary to reading and that reading takes precedence in terms of priority. Because of the No Child Left Behind Act, priority is being placed on reading because schools are being asked to become more accountable than ever for assessing reading. As a result, subjects such as science, math, and technology are taking a back seat. Students in this project expressed concerns about this situation and strongly believe that the Toying With Technology course is a positive step in addressing this situation.

Summary

As a researcher and educator in teacher preparation with plans of going into higher education in the areas of science and technology, I hope to have a direct impact and contribute to the profession by creating an initiative for teacher reform in engineering, science, and technology. The results from this study provided new direction for teacher educators of science and technology as well as teacher preparation programs that wish to improve the quality of preservice teacher experiences in science and technology and who wish to consider engineering as a context to do this.

REFERENCES

Abell, S., & Roth, M. (1992). Constraints to teaching science: A case study of a science teacher enthusiast. *Science Education.* 76(6), 581-95.

Ackerman, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference? Retrieved on February 25, 2004 from http://learning.media.mit.edu/publications.html

Ackerman, E. (1996). Perspective-taking and object construction. In Y. Kafai & M. Resnick (Eds.), *Constructionism in Practice* (pp. 25-35). New Jersey: Lawrence Erlbaum Associates.

Aguirre, J.M., Haggerty, S.M., & Linder, C.J. (1990). Student-teachers' conceptions of science, teaching and learning: a case study in preservice science education. *International Journal of Science Education,*12(3), 38.

Alesandrini, K. & Larson, L. (2002). Teachers bridge to constructivism. *Clearing-House.* 75(3), 118-122.

American Association for the Advancement of Science. (1993). *Science for all Americans: Project.* New York: Oxford.

American Association for the Advancement of Science. (1990). *Science for all Americans: Project 2061.* New York: Oxford University Press.

Anderson-Rowland, M.R.,, Baker, D.R., Secola, P.M., Smiley, B.A., Evans, D.L., & Middleton, J.A. (2002). *Integrating engineering concepts under current K-12 State and national tandards.* American Society for Engineering Education.

Appleton, K. (1995). Student teachers' confidence to teach science: is more science knowledge necessary to improve self-confidence. *International Journal of Science Education.*

Atwater, M.M., Gardner, C., & Knight, C.R. (1991). Beliefs and attitudes of urban primary teachers toward physical science and teaching physical science. *Journal of Elementary Science Education.*

Babbie, E. (2001). *Practice of social research.* 9th Ed. Belmont, CA: Wadsworth Thompson Learning.

Bell, B.F & Pearson, J. (1992). Better learning. *International Journal of Science Education* 14(3), 349-361.

Bencze, L., & Hodson, D. (1998). Changing practice by changing practice: Toward more authentic science and science curriculum development. *Journal of Research in Science Teaching*, 20(6), 683-694.

Bentley, M. L., Ebert, C., & Ebert, E. (2000). *The natural investigator: A constructivist approach to the teaching of elementary school science*. Belmont, CA: Wadsworth/Thomson Learning.

Bogdan, R.C., & Biklen, S.K. (1982). *Qualitative research for education: An introduction to theory and methods*. Boston, MD: Allyn and Bacon, Inc.

Boston, B.O. (2000). *Before it's too late: A report to the nation from the national commission on mathematics and science teaching for the 21st century*. Jesup, MD: Education Publications Center.

Boyer, Ernest L. (1983). *High school: A report on secondary education in america*. New York: Harper and Row.

Brooks, J.G., & Brooks, M.G. (1993). *In search for understanding: The case for constructivist classrooms*. Alexandria, VA: Association for Supervision and Curriculum Development.

Brush, J., & Evans, D. (2002). Developing a state technology plan to promote state-wide technology integration in k-12 education: preparing arizona students for future success. *Association for the Advancement of Computing in Education*.

Burgess, R.G. (1985). *Field methods in the study of education*. Philadelphia: The Falmer Press.

Carnes, G.N. (2002). Interpreting elementary teacher candidates' images of science teaching. University of South Carolina, Columbia: SC.

Carr, A.A., Jonassen, D.H., Litzinger, M.E., & Marra, R.M. (1998 January-February). Good ideas to foment educational revolution: The role of systemic change in advancing situated learning, constructivism, and feminist pedagogy. *Educational Technology*.

Champion, R. (2002). What to do when the data are words. National Staff Development Council.

Chenail, R.J. (1995). Presenting qualitative data. The Qualitative Report [Online serial], 2(3). Retrieved on June 3, 2004 from http://www.nova.edu/ssss/QR/QR2-3/presenting.html.

Cobern, W.W., & Loving, C.C. (2002). Investigation of preservice elementary teachers' thinking about science. *Journal of Research in Science Teaching*.

Coffey, A., & Atkinson, P. (1996). Concepts and coding. In A. Coffey & P. Atkinson, *Making sense of qualitative data.* Thousand Oaks, CA: Sage.

Cole, P. (1994). Finding a path through the research maze. *The Qualitative Report*, 2(1). Retrieved June 1, 2004 from http://www.nova.edu/ssss/QR/BackIssues/QR2-1/index.html.

Committee on Education and Human Resources. (1993). *The federal investment in science, mathematics, engineering, and technology education: Where now? What next?* Report of the Expert Panel for the Review of Federal Education Programs in Science, Mathematics and Technology to the Federal Coordinating Council for Science, Engineering and Technology. Washington, DC.

Committee on Science and Mathematics Teacher Preparation. (2001). *Educating teachers of science, mathematics, and technology: New practices for the new millennium.* Washington, DC: Academy Press.

Creighton, L. (2002). *The abc's of engineering.* ASEE Prism Online, 12(2). Retrieved on February 27, 2004 from http://www.prism-magazine.org/nov02/abc.cfm.

Cresswell, J.W. (1994).*Research design: Quantitative and qualitative approaches.* London: Sage Publications.

Cresswell, J.W. (1998). *Qualitative inquiry and research design: choosing among five traditions.* Thousand Oaks, Ca: Sage Publications, Inc.

deGrazia, J.L., (2001). *Engineering workshops for k-12 schoolteachers*, Proceedings, 2001 Frontiers in Education Conference, paper #1297. Institute of Electrical and Electronics Engineers.

Denzin, N., & Lincoln, Y. (Eds.). (1994). *Handbook of qualitative research.* Thousand Oaks, CA: Sage.

Eisner, E.W., & Peshkin, A. (1990). *Qualitative inquiry in education: The continuing debate.* New York: Teachers College Press.

Erwin, B. (2001). *K-12 education and systems engineering: A new perspective.* Proceedings of the American Society of Engineering Education National Conference, July 1998, Seattle, WA, session 1280.

Federal Coordinating Council for Science, Engineering and Technology. (1993). *The federal investment in science, mathematics, engineering, and technology education? Where now? What next? Report of the expert panel for the review of federal education programs in science, mathematics, engineering, and technology.* Washington, DC: Author. (ERIC Document Reproduction Service No. ED 366 500)

Feiman-Nemser, S., & Remillard, J. (1996). Perspectives on learning to teach. In F. B. Murray (Ed.), *The teacher educator's handbook* (pp. 63-92). San Francisco: Jossey-Bass.

Ferrari, M., Ferrari, G., and Hempel, R. (2001). *Building robots with lego mindstorms: The ultimate tool for mindstorms maniacs.* Syngress Media Inc.

Fosnot, C.T. (Ed.) (1996). *Constructivism: theory, perspectives and practice.* New York: Teachers College Press.

Fox, R. (2001). Constructivism examined. *Oxford Review of Education*, 26(1), 23-35.

Funk, C. (2003). James otto and the pi man: A constructivist tale. *Phi Delta Kappan*, 85(3), 212-214.

Gall, M. D., Borg, W. R., & Gall, J. P. (1996). *Educational research: An introduction.* White Plains, NY: Longman.

Gallagher, M., & Bauerle, A. (2003, March). *Toying with technology: bridging the gap between education and engineering.* Paper presented at the Society for Information Technology and Teacher Education, SITE Conference, Albuquerque, NM.

Genalo, L. & Gallagher, M. (2002). *Practicing teachers in a graduate engineering course.* Paper presented at the meeting of the American Society for Engineering Education, ASEE Annual Conference, Montreal, Canada.

Genalo, L.J., & Gallagher, M. (1998). *Practicing teachers in a graduate engineering course*, Paper presented at the meeting of the American Society for Engineering Education, ASEE Annual Conference, Session # 3553.

Genalo, L.J., Wright, C.T., Wright, K.B., & Collier, C.L., (1997, June). *Toying with technology: Mobile robots and high school interns*, Paper presented at the meeting of the ASEE Annual Conference, on CD - Session # 1692.

Gerald, D.E., & Williams, H. (1998). *Projections of educational statistics to 2008.* Washington, DC: U.S. Department of Education National Center for Educational Statistics.

Gil-Perez, D., Guisasola, J., Moreno, A., Cachapuz, A., Pessoa de Carvalho, A., Torregrosa, J., Salinas, J., Valdes, P., Gonzalez, E., Duch, A., Dumas-Carre, A., Tricarico, H., Gallego, R. (2002). Defending constructivism in science education. *Science and Education,* 11(6), 557-571.

Gillingham, M., & Topper, A. (1999). Technology in Teacher Preparation: Preparing Teachers for the Future. *Journal of Technology and Teacher Education*, 7(4), 303-321.

Gorham, D., Cantrell, P., Kleppe, J., Hanson, C., Morrison, G., Johnson, W., & Rhoads, T.R. (2003). *Colleges of engineering and education: partnering for effective community outreach*. American Society for Engineering Education.

Gros, B. (2002). Knowledge construction and technology. *Journal of Educational Multimedia and Hypermedia*. Retrieved May 2, 2004 from http://dl.aace.org/11526.

Hacker, M., & Barden, R. (1993). *Living with technology*. New York: Delmar Publishing Inc.

Hare, S., Howard, E., & Pope, M. (2002). Technology integration: Closing the gap between what preservice teachers are taught to do and what they can do. *Journal of Technology and Teacher Education*, 10(2), 191-203.

Hargrave, C.P. & Hsu, Y.S. (2000). Survey of instructional technology courses for preservice teachers. *Journal of Technology and Teacher Education*, 8(4) p. 303-314.

Harlen W, & Holroyd C (1997) Primary teachers' understanding of concepts of science: impact on confidence and teaching. *International Journal of Science Education*, 27(3), 323-338.

Howes, E.V. (2002). Learning to teach science for all in elementary grades: What do preservice teachers bring? *Journal of Research in Science Teaching*, 39(9), 845-869.

Hunt, J.B., & Carroll, T. G. (2003). *No dream denied: A pledge to america's children*. National Commission On Teaching and America's Future. Washington.

International Society for Technology in Education (2000). *National educational technology standards*, Eugene, Oregon.

International Technology Education Association. (2000). *Technology for all Americans project. Standards for technological literacy:* Content for the Study of Technology: Reston, VA.

International Technology Education Association. (1996). *Technology for all Americans: A rationale and structure for the study of technology*. Technology for All Americans Project: Reston, VA.

Jenkins, E.W. (2000). Constructivism in school science education: Powerful model or the most dangerous intellectual tendency? *Science & Education*, 9 pg. 599-610.

Jonassen, D. H. (1995, July-August 1995). Supporting communities of learners with technology: A vision for integrating technology with learning in schools. *Educational technology*, 60-63.

Jonassen, D.H. (1991). Objectivism vs. constructivism: Do we need a new philosophical paradigm shift? *Educational Technology: Research & Development*, 39(3).

Kanstoroom, M. (1999). *Qualified math and science teachers: Rethinking the regulatory approach.* Thomas B. Fordham Foundation & Manhattan Institute.

Kaufman, R. (1992). NRC report sparks debate among computer scientists. *The Scientist*, 16(17).

Larkin-Hein, T., Prejean, A.I., Irvine, S.E., & Vasquez, V. (2002). Interdisciplinary teaching & learning in middle school classrooms: A technology-rich, constructivist-based approach. *American Society for Engineering Education.*

Levitt, K.E. (2001). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education*, 86, 1-22.

Lichtman, M., & Taylor, S.I. (1993). *Conducting and reporting case studies.* Paper presented at the Annual Meeting of the American Educational Research Association, Atlanta GA. (ERIC Document Reproduction Service No. ED358157).

Lincoln, Y.S., & Guba, E.G. (1985). *Naturalistic inquiry.* Beverly Hills: Sage Publications.

Marshall, C. and Rossman, G.B. (1999). *Designing qualitative research* (3rd ed.). Thousand Oaks: Sage Publications

McKinney, M., Jones, W., Strudler, N., & Quinn, L. (1999). First-year teachers' use of technology: preparation, expectations and realities. *Journal of Technology and Teacher Education*, 7(2), 115-129.

McIntosh, H. (1993). Technology is changing basic structure of education. *News Report,43*(3), 2-5.

Mehra, B. (2002). Bias in qualitative research: voices from an online classroom. The qualitative report [Online Serial], 7(1). Retrieved on March 30, 2004 from http://www.nova.edu/ssss/QR/QR7-1/mehra.html.

Merriam, S.B. (2001) *Qualitative research and case study applications in education.* Jossey-Bass Publishers: San Francisco.

Merriam, S.B. (1998). *Qualitative research and case study applications in education.* San Francisco, CA: Jossey-Bass.

Merriam, S. (1988). *Case study research in education: A qualitative approach.* San Francisco: Jossey-Bass.

Michem, K., Wells, D.L., Wells, J.G. (2003). Effective integration of instructional technologies (IT): Evaluating professional development and instructional change. *Journal of Technology & Teacher Education*, 11(3), 397-414.

National Center for Education Statistics (NCES) (2000). *Teachers' tools for the 21st century: A report on teachers' use of technology.* Retrieved on May 20, 2004, from http://nces.ed.gov/pubs00/2000102.htm

National Commission on Mathematics and Science Teaching for the 21st Century. (2000). *Before it's too late: A report to the nation from the national commission on mathematics and science teaching for the 21st century.* Washington, DC: U. S. Department of Education. [Available online at: http://www.ed.gov/americacounts/glenn/]

National Commission on Teaching and America's Future (1996). *What matters most: Teaching for America's future*, National Commission on Teaching and American's Future, New York.

National Research Council (2001). *National science education standards.* Washington, DC: National Academy Press.

National Research Council (1996) *National science education standards.* Washington, DC: National Academy Press

National Research Council (1992) *National science education standards.* Washington, DC: National Academy Press.

National Science Foundation (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology.* National Science Foundation. Arlington, VA.

National Science Teachers Association (1996). *National science teachers association Science standards.* Washington: DC.

National Survey of Science and Mathematics Education (2000). *Status of elementary school science teaching.* National Science Foundation under grant number REC-9814246.

Papert, S. (1991). *Situating constructionism in constructionism.* I. Harel and S. Papert (eds). Norwood, New Jersey, Ablex Publishing.

Patton, M.Q. (1985, April). *Quality in qualitative research: Methodological principles and recent developments.* Invited address to Division J of the American Educational Research Association, Chicago, IL.

Patton, M.Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Peshkin, A. (1990). *Qualitative inquiry in education: The continuing debate.* New York: Teachers College Press.

Piaget, J. (1970). *The science of education and the psychology of the child.* NY: Grossman.

Platt, J. (1992). Case study in American methodological thought. *Current Sociology*, 40, 17-48.

Plourde, L. A., Alawiye, O. (2003). Constructivism and elementary preservice science teacher preparation: Knowledge to application. *College Student Journal*, 37(3).

Richard Feynman (1995). *National science education standards.* In National Academy of Science, (Eds), Retrieved on May 5, 2004 from http://books.nap.edu/html/nses/html/action.html.

Rieber, L.P. (1993). A pragmatic view of instructional technology. In K. Tobin (Eds.), *The Practice of Constructivism in Science Education* (pp. 193-212). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Rigden, J. (1993). NSF study finds many teachers unprepared for instructing children in the sciences. In B. Spector, *The Scientist*, Retrieved on April 2, 2004 from http://www.the-scientist.com/yr1993/sep/spector_p1_930920.html

Robson, C. (2002). *Real world research (2d ed).* Blackwell, Oxford.

Rushton, E., Cyr, M., Gravel, B., & Prouty, L.(2002, June). *Infusing engineering into public schools.* Paper presented at the Annual Meeting of the American Society of Engineering Education. Montreal.

Rutherford, F.J., & Ahlgren, A. (1990). *Science for all Americans.* New York: Oxford University Press.

Sanoff, Alvin P. (2001). Under the magnifying glass. *Prism.* 11(2), 36-38.

Schaefer, M.R., Sullivan, J.F., and Yowell, J.L. (2003). *Standards-based engineering curricula as a vehicle for k-12 science and math integration.* ASEE Conference Proceedings.

Schoon, K.J., & Boone, W.J. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education*, 82, 553-568.

Shaw, A. (1996). Social constructionism and the inner city: Designing environments for social development and urban renewal. In Y. Kafai & M. Resnick (Eds.), *Constructionism in Practice* (pp. 175-206). New Jersey: Lawrence Erlbaum Associates.

Shelly, G.B., Cashman, T.J., Gunter, R.E., Gunder, G.A. (2004). *Teachers discovering computers: integrating technology in the classrooms.* Boston: Thompson Course Technology.

Sherlock Holmes in the Boscombe Valley Mystery by A. Conan Doyle (Origianally published in The Strand, October, 1891). Retrieved on April 2, 2004 from http://www.geocities.com/sherlockiana/sherlock/adv/sherlock_bosc.html

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reforms. *Harvard Educational Review*, 37(l), 1-22.

Simons, H. (1996). The paradox of case study, *Cambridge Journal of Education*, 26(2), 225-40.

Southerland, S.A., & Gess-Newsome, J. (1998). Preservice teachers' views of inclusive science teaching as shaped by images of teaching, learning, and knowledge. *Science Education.*

Sprague, D., & Dede, C. (1999). *If I teach this way, am I doing my job*? ISTE Publications. Retrieved on June 1, 2004 from http://www.iste.org/LL/27/1/06s/index.cfm

Stake, R. (1995). *The art of case research.* Thousand Oaks, CA: Sage Publishing.

Stephenson, W., & Johnson, J. (1992). *White paper on k-16 community outreach: engineering and education perspectives.*

Sullivan, J.F., Davis , S.E., deGrazia, J.L. & Carlson, D.W. (1999). *Beyond the pipeline: building a k-12 engineering outreach program.* Proceedings, 1999 Frontiers in Education Conference.

Szekeres, T., & Vasarhelyi, Z. (1998). *The development of staff participation in teacher-engineer training.* In: A. Toth (ed.): Staff Development in Technical Teacher Training. Budapest, ATEE.

Thompson, A., Schmidt, D. & Davis, N. (2003). Technology collaboratives for simultaneous renewal in teacher education. *Educational Technology Research and Development*, 51(1), pp.73-89.

Thompson, A. E., & Schmidt, D. (1999). *Technology collaboratives for simultaneous renewal in teacher education (preparing tomorrow's teachers to use technology grants).* Ames, Iowa: Iowa State University, Center for Technology and Learning in Teaching.

Topp, N. (1996). Preparation to use technology in the classroom: Opinions by recent graduates. *Journal of Computing in Teacher Education*, 12(4), 24-27

U. S. Congress, Office of Technology Assessment. (1995). *Teachers and technology: Making the connection*. OTA-EHR-616 Washington, DC: U. S. Government Printing Office.

U.S. Department of Education (2004). *Preparing tomorrow's teachers to use technology Program (PT3).* Retrieved on May 17, 2004, from http://www.ed.gov/programs/teachtech/index.html

U.S. Department of Education (2003). *No child left behind toolkit for teachers*, Retrieved on June 30, 2004, from http://www.ed.gov/teachers/nclbguide/nclb-teachers-toolkit.pdf

U.S. White House (2001). *Improving math & science education so that no child is left behind,* Retrieved May 5, 2004, from http://www.whitehouse.gov/news/reports/no-child-left-behind.html#5

Vannatta, R., Beyerbach, B., & Walsh, C. (2001). From teaching technology to using technology to enhance student learning: Preservice teachers' changing perceptions of technology infusion. *Journal of Technology and Teacher Education*, 9(1), 105-127.

Wilson, B. G. (Ed.) (1996). *Constructivist learning environments: Case studies in instructional design*. Englewood Cliffs, NJ: Educational Technology Publications.

Wilson, S., & Gudmundsdottir, S. (1987). What is this a case of? Exploring some conceptual issues in case study research. *Education and Urban Society*, 20(1).

Yerrick, R. (2003). *Learning from children's voices & improving science education.* Retrieved May 5, 2004, from http://ali.apple.com/ali_sites/ali/exhibits/1000344/Professional_Development.html

Yerrick, R. (2002, December 12). Utilizing digital video to expand prospective science teachers' views of science. Exchanges: *The Online Journal of Teaching and Learning in the CSU.* Retrieved May 5, 2004, from http://www.exchangesjournal.org/print/print_1092.html

Yin, R.K. (1994) *Case study research: Design and methods*, (2nd ed.) Beverly Hills, CA: Sage.

Yin, R. (1989a). *Case study research: Design and methods* (Rev. ed.). Beverly Hills, CA: Sage Publishing.

Zachary, L.W., Sharp, J.M., & Adams, B.M. (2000, June). *Engineering connections: teaching engineering mechanics to k-12 teachers*. Proceedings of American Society of Engineering Education, St. Louis, MO.

APPENDIX A. DOCUMENTATION OF HUMAN SUBJECTS APPROVAL

Exempt 3/5/03

OFFICE USE ONLY	Key Personnel Training: ☑ Completed	IRB Review Date: ______
Project ID# 03-463	☐ Incomplete*	IRB Approval Date: ______
Oracle ID# ______	*If incomplete, date completed: ______	IRB Expiration Date: ______

ORIGINAL
IRB
MAR 0 3 2003

Iowa State University
Human Subjects Review Form

(Please type this form & submit the original & two copies with three copies of all attachments)

1. Title of Project: A cohort approach to integrating engineering and technology into preservice education

2. I agree to provide the proper surveillance of this project to insure that the rights and welfare of the human subjects are protected. I will report any adverse reactions to the committee. Additions to or changes in research procedures after the project has been approved will be submitted to the committee for review. I agree that all key personnel involved in conducting human subjects research will receive training in the protection of human subjects. This also includes all PI's and Co-PI's. Access to the 45 CFR 46, Belmont Report, and ISU's Federal Wide Assurance is available to all PI's via the WWW. http://grants-svr.admin.iastate.edu/VPR/humansubjects.html. I agree to request renewal of approval for any project continuing more than one year.

Melinda Ann Gallagher — 2/17/03 — [signature]
Typed name of principal investigator — Date — Signature of principal investigator

Curriculum & Instruction — 3316 Emerald Drive, Ames, IA. 50010
Department — Mailing Address for Correspondence

(515) 233-8234 mgallagh@iastate.edu
Phone number and email

2a. Principal investigator
☐ Faculty ☐ Staff ☐ Postdoctoral ☒ Graduate Student ☐ Undergraduate Student

3. Typed name of co-principal investigator(s) — Date — Signature of co-principal investigator(s)

Dr. Ann Thompson — 2/17/03 — Ann Thompson

3a. Co-Principal investigator(s) (check all that apply)
☒ Faculty ☐ Staff ☐ Postdoctoral ☐ Graduate Student ☐ Undergraduate Student

3b. Typed name of major professor or supervisor (if not a co-principal investigator) — Date — Signature of major professor or supervising faculty member

4. Typed names of other key personnel who will directly interact with human subjects. (all key personnel must have training before approval will be made)

5. Project (check all that apply)
☐ Research ☒ Thesis or dissertation ☐ Class project ☐ Independent Study (490, 590, Honors project)

6. Number of subjects (complete all that apply)
_____ # adults, non-students 21 # ISU students _____ # other (explain)
_____ # minors under 18 (must obtain assent from minor & parental consent)

APPENDIX B. PARTICIPANT CONSENT FORM

A Cohort Approach to Integrating Engineering and Technology into Preservice Teacher Education

You are invited to participate in a research study: A Cohort Approach to Integrating Engineering and Technology into Preservice Teacher Education. The purpose of this study is to gain and understanding of the following: preservice teachers' attitudes about learning in a constructivist/constructionist environment, how preservice teachers view and value learning about the field of engineering, and how students view participating in a cohort.

The methods used to collect information for this study are as follows: personal interviews, design notebooks, WebCT postings and chats, video, classroom observations, group discussions, e-mail, classroom assignments, and feedback questions.

As a participant in this study, you are encouraged to ask questions at any time concerning the nature of this study and the methods that are being utilized. Your suggestions and concerns are important so please contact me at any time at the phone number/e-mail address listed below.

As a participant in this study, there are no foreseeable risks or discomforts to you. Participation in this study is voluntary and you may decline to participate without penalty. If you decide to participate, you may withdraw from this study at any time without penalty and the data pertaining to your participation will be destroyed or returned to you. Benefits from this study will include observations of the educational research process in order to promote professional development and support of our profession.

If at any time you have questions or concerns about your participation in this study, you may contact me, Melinda Gallagher, researcher, at 2220 Howe Hall, Iowa State University, Ames, IA, 50010; 294-3882; mgallagh@iastate.edu. You may also contact Dr. Ann Thompson, my major professor at N108 Lagomarcino Hall, Iowa State University, Ames, IA, 50010; 294-5287; eat@iastatate.edu.

I consent to participate in the research study named and described above:

Name: (Printed)____________________________________
Date:____________

Signature:____

Researcher Name:__________________________________ **Date:**____________

Researcher Signature:________________________________

APPENDIX C. POST ENGINEERING QUESTIONNAIRE

Post Engineering Questionnaire

*Please answer these questions as completely as possible

1. Since you left the Toying With Technology course approximately one year ago, have you replicated any of the engineering activities that you participated in during the course?
2. Since last spring, have you had an opportunity to use any engineering knowledge that you gained in the Toying With Technology course? If so, please explain.
3. When you move into your future classroom, can you see yourself teaching your students about engineering or teaching using engineering concepts? Explain
4. Do you think it is important for K-12 students to gain an understanding about engineering? Why or why not?
5. Has your view of engineering changed in the past year, if so how?
6. What was the most valuable experience(s) during the Toying With Technology course? Explain.
7. What are your views on using WebCT in the Toying With Technology course? Explain.
8. Did you feel WebCT was an important part of the Toying With Technology course? Explain.
9. Have your views changed on cohorts? Explain.
10. What are some advantages and disadvantages to working in a cohort environment? Explain.
11. Anything else you would like to share with me?

APPENDIX D. STUDENT JOURAL EXAMPLE

1-22

1) 3 successes

1) Able to understand what some begining language is

2) Figured out that running time determines distance - could apply to any distance requested

3) made it through 1st day of programming

2) 3 unsuccessful situations

1) our car turned opposite direction it was supposed it

2) we never got the program to run the way it should have

3) 1st trial did nothing we thought it would

3) we found it easier to physically drive the car ourselves & talk out what needs to happen, then we tried writing a program.

4) YES - we did several trial & errors

5) I thought it was easier than expected but still have ALOT to learn. I like new challenging situations like this programming.

6) 3 learned things

1) How to compile & download program

2) New programming vocab

3) that you can turn off, 1 motor

1-24

1) Was successes
   1) We finished Program 1
   2) We finished Program 2
   3) Started Program 3 have a good idea how to do it - but ran out of time
2) Problems
   1) Our car kept falling apart - we had to stop & fix it several times
   2) We kept getting vocab error - had to compile vocab program several times
   3) ~~[illegible]~~ we struggled with Prog 3 for awhile - we just did trial & error

3) How did your partner help p.s.
   She would come up with ideas I never thought of - figured out we had to download & compile vocab program before we tried to compile our program

4) Interesting experience
   We just felt like we were catching on really fast & understood alot more than class on Tues. We were shocked @ ourselves

5) Learn To & not to do
   To: compile 1st & download (vocab prog) before we start
   Turn car on before open mindstorms

Don't: Give up or get fustrated-
you'll figure it out sometime
Don't rush - take time to think
out what your going to do

6) Engineers in a car
Mechanical - put together car
Chemical - batteries
Electrical - fuses
Computer - program cars special features

7) Why teamwork is important
Two Brains are better than 1-
2 people give you a chance to
think of more & better ideas -
& 2 people can challenge your
thoughts & may catch your errors

1-29

Success

I feel that I have learned so much in your class. I love being challenged & this can defintly be a challenging class. I have come to find myself having more successes each class period! I think that class on Tuesday was just a successful day! Everything seem to 'click' in. First, we started out really slow & fustrated. We couldn't even get our car to move. Then with some guided help everything started to fall into place. We figured out how to work the light sensors & what a threshold means. Once we figured that out we just got on a roll! We were able to finish the entire Program #3 in one class period. We got our car to stay within the track - turn around when it got to a black line. Then we were able to program our car to follow the black track without stopping or getting off the track. So then we moved onto Program #4. We figured the best way to put two ligh sensors on the car and how to make it follow the red road exactly. We started to program the car for the black obstacle course, but ran out of time. I feel the 'one' word to sum up Tuesday was SUCCESSFUL!

Problem Solving

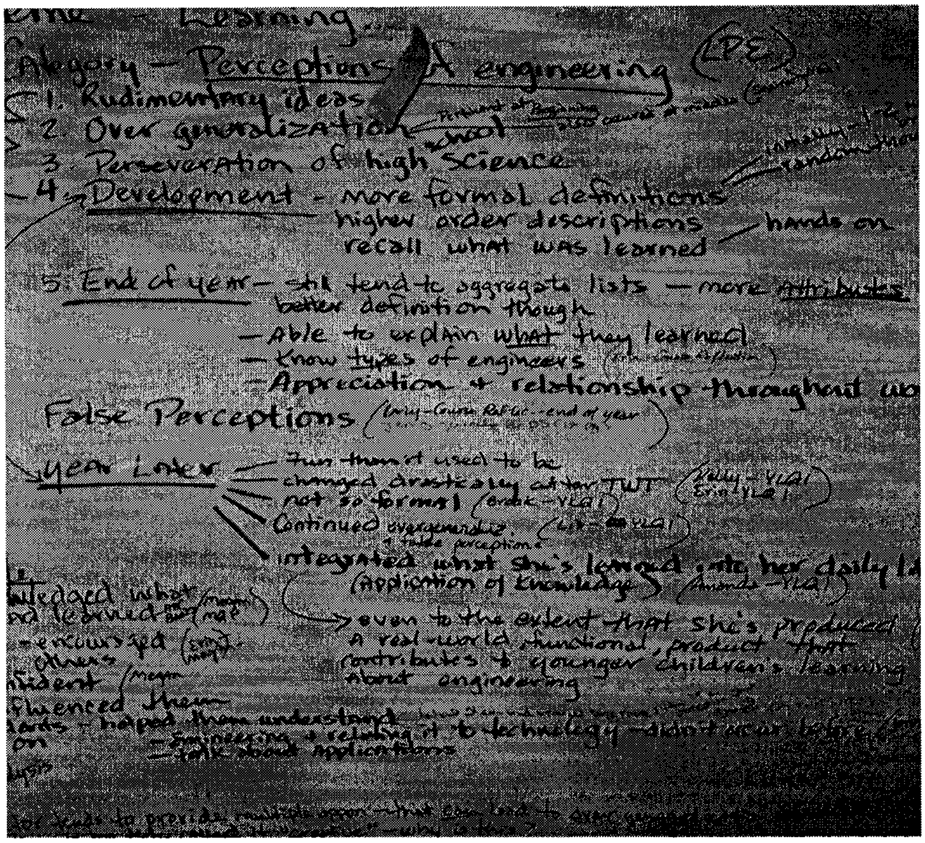
In this class we learn to problem solve, and we learn this daily. It is extremely rare to walk into class, start programming, compile & download a program, run it, and have it work and do exactly what you are wanting to make it do. You have to problem solve. It is helpful that you have a partner to work with. Sometimes they come up with ideas that you would never think of. I have learned several different ways to problem solve. One way is to mentally plan out what you want your program to do. Another way, which I find helpful is to physically move the car & plan what it needs to do at all times. Another way is to talk your way through the program- say exactly what the car will do at each step- this, I have found very useful. I dont think I have ever problem solved so much in my life. I enjoy it, but you have to be able to deal with extreme fustrations. Sometimes you may feel there is nothing else you could try or do to make it work, but you know it can be done so it brings you back to one of the most important aspects of this class- PROBLEM SOLVING!

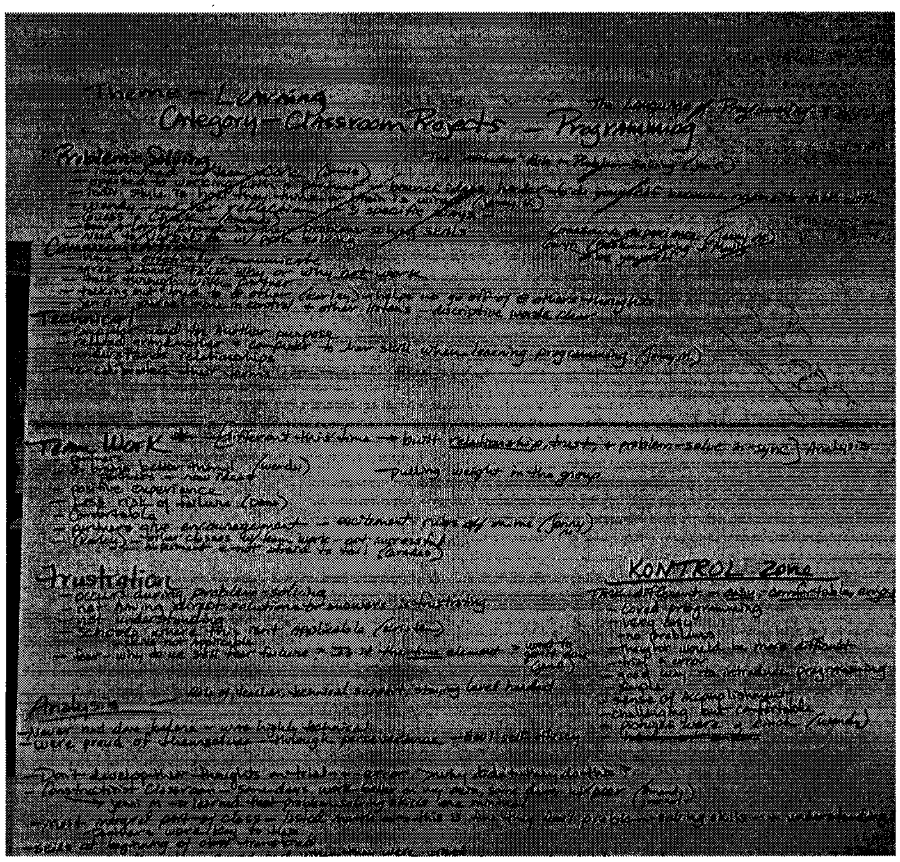
APPENDIX E. PERSONAL INTERVIEW SAMPLE QUESTIONS

Sample Interview Questions

1. What is engineering?
2. What is technology?
3. Explain constructivism.
4. Did you ever experience “engineering” in K-12? If so, how?
5. Is it important to teach engineering principles and concepts in the K-12 classroom? Explain
6. Describe how participating in a cohort effects your learning in the Toying With Technology course.

APPENDIX F. DATA ANALYSIS WALL CHARTS

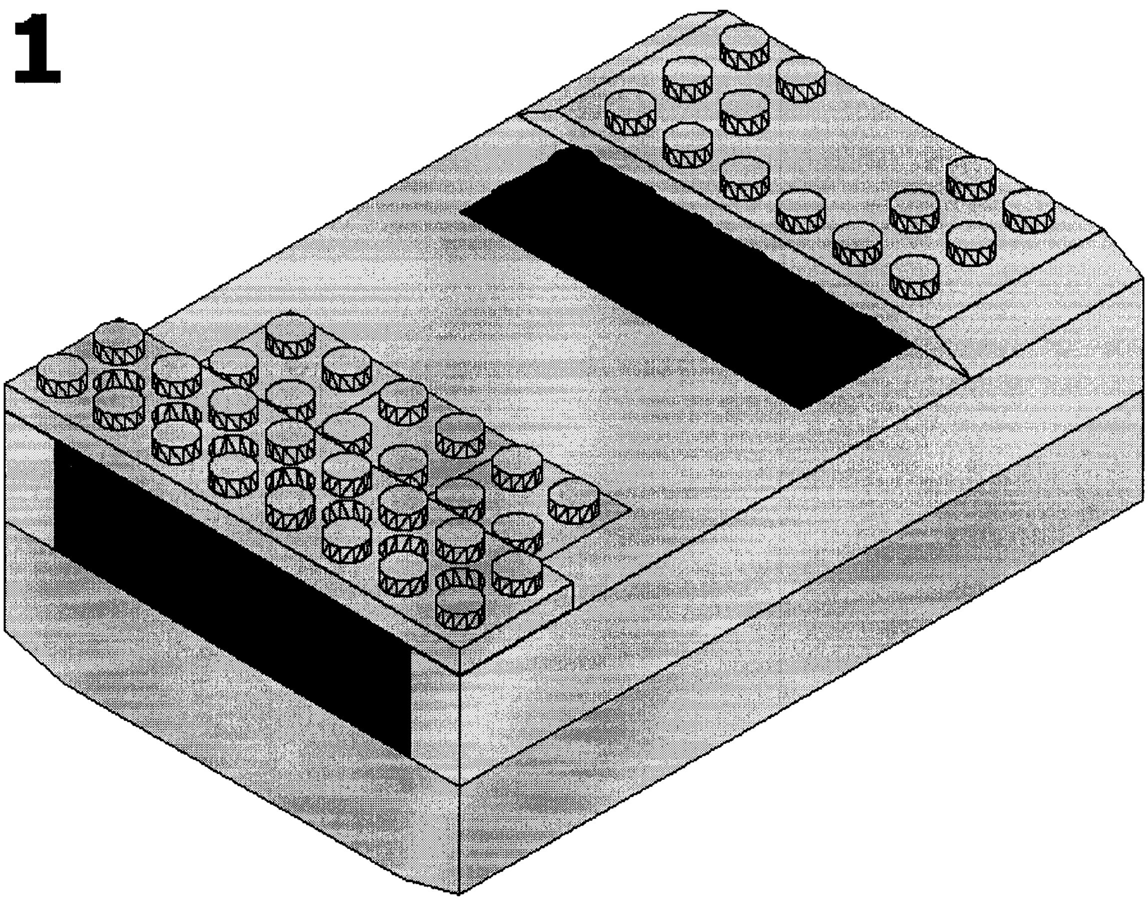

Theme – Learning
Category – Perceptions of engineering (LPE)
1. Rudimentary ideas
2. Over generalization
3. Perseveration of high school science
4. Development – more formal definitions
higher order descriptions — hands on
recall what was learned
5. End of year – still tend to aggregate lists — more attributes
better definition though
– Able to explain what they learned
– know types of engineers
– Appreciation & relationship throughout wo…
False Perceptions
year later – fun than it used to be
– changed drastically after TWT
– not so formal
– Continued overgeneralization & false perceptions
– integrated what she's learned into her daily li…
(Application of knowledge)
→ even to the extent that she's produced a real-world functional product that contributes to younger children's learning about engineering


Theme – Learning
Category – Classroom Projects – Programming
Problem Solving
Communication
Technology
Team Work
Frustration
KONTROL Zone
Analysis

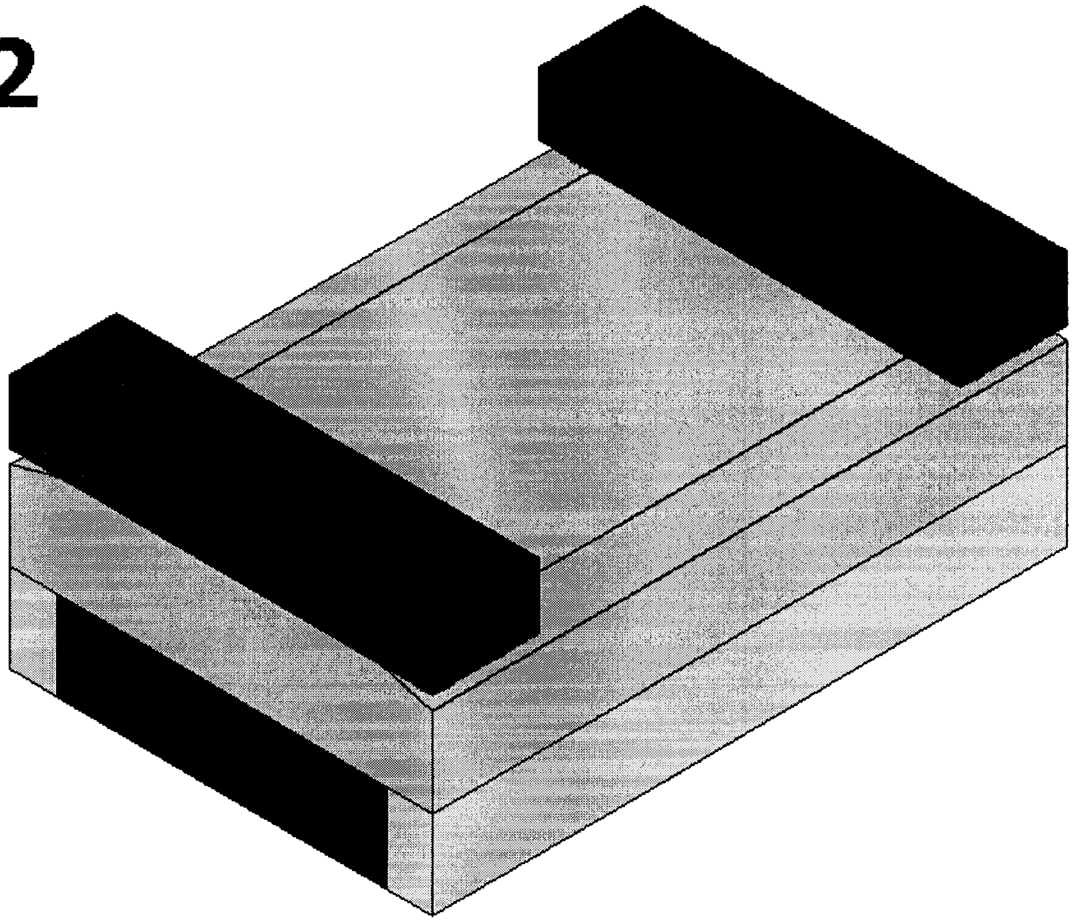
APPENDIX G. LEGO ROBOTIC CAR INSTALLATION INSTRUCTIONS

Mindstorms Rover

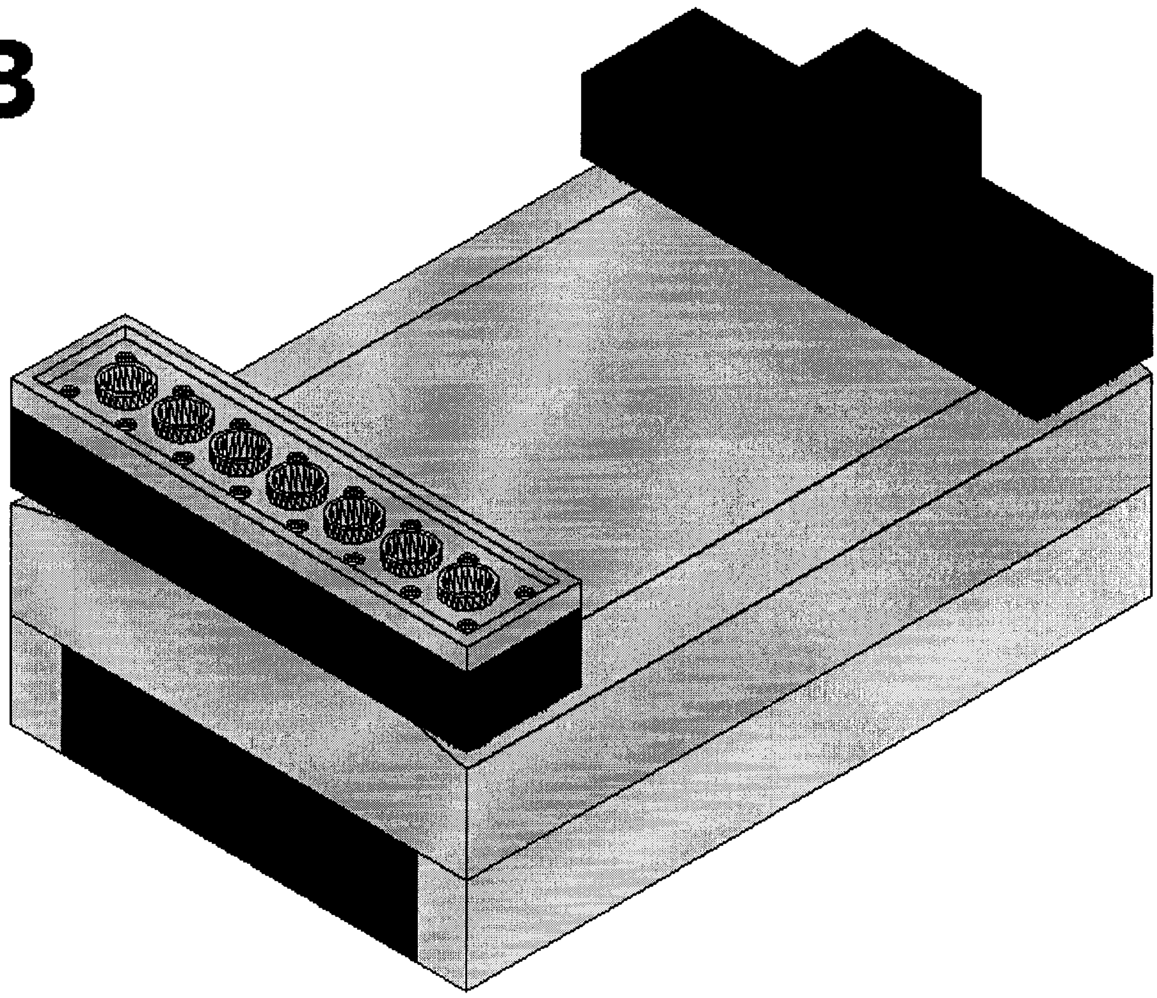
1



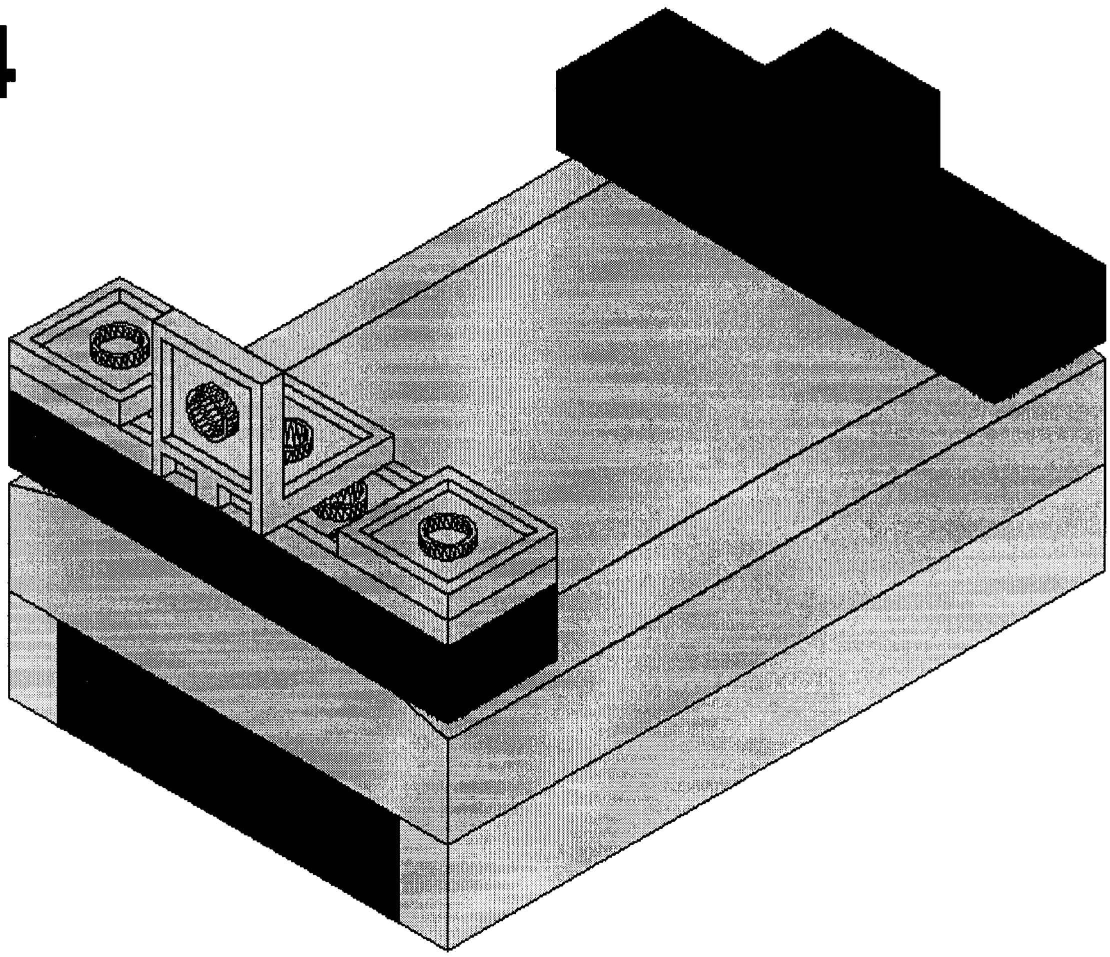
2



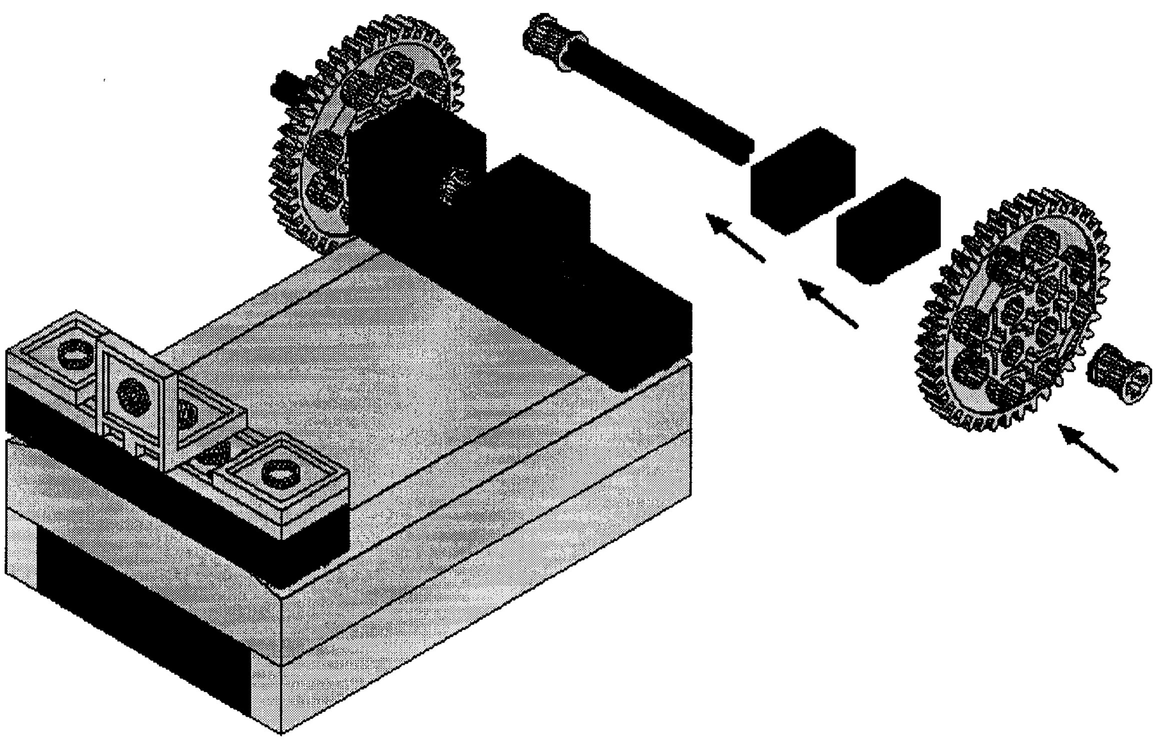
3



4



5



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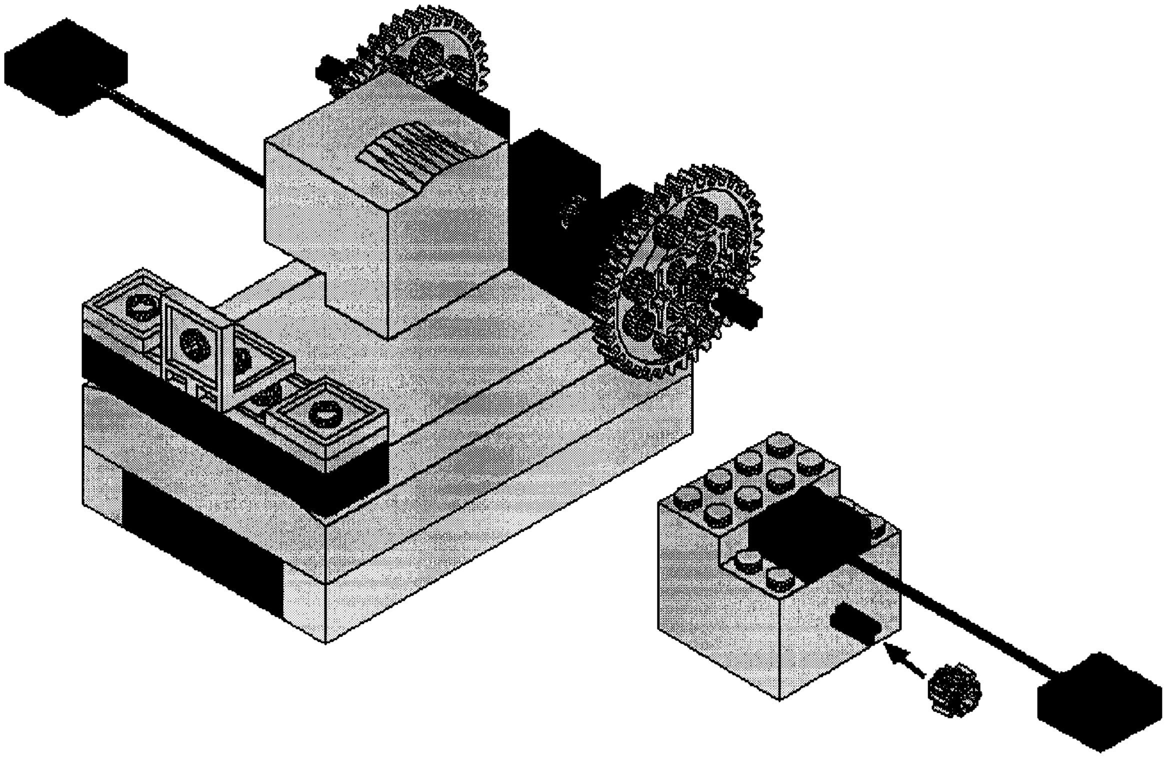

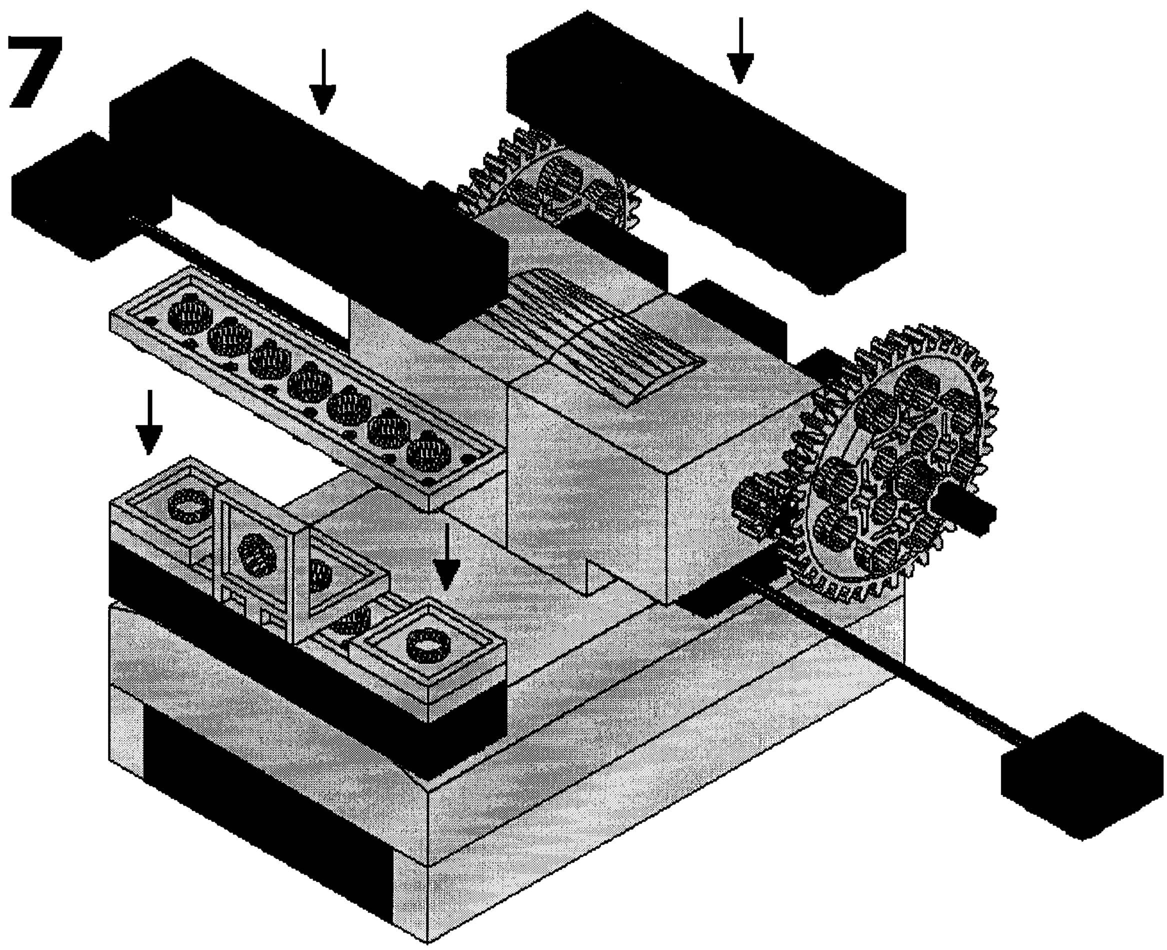

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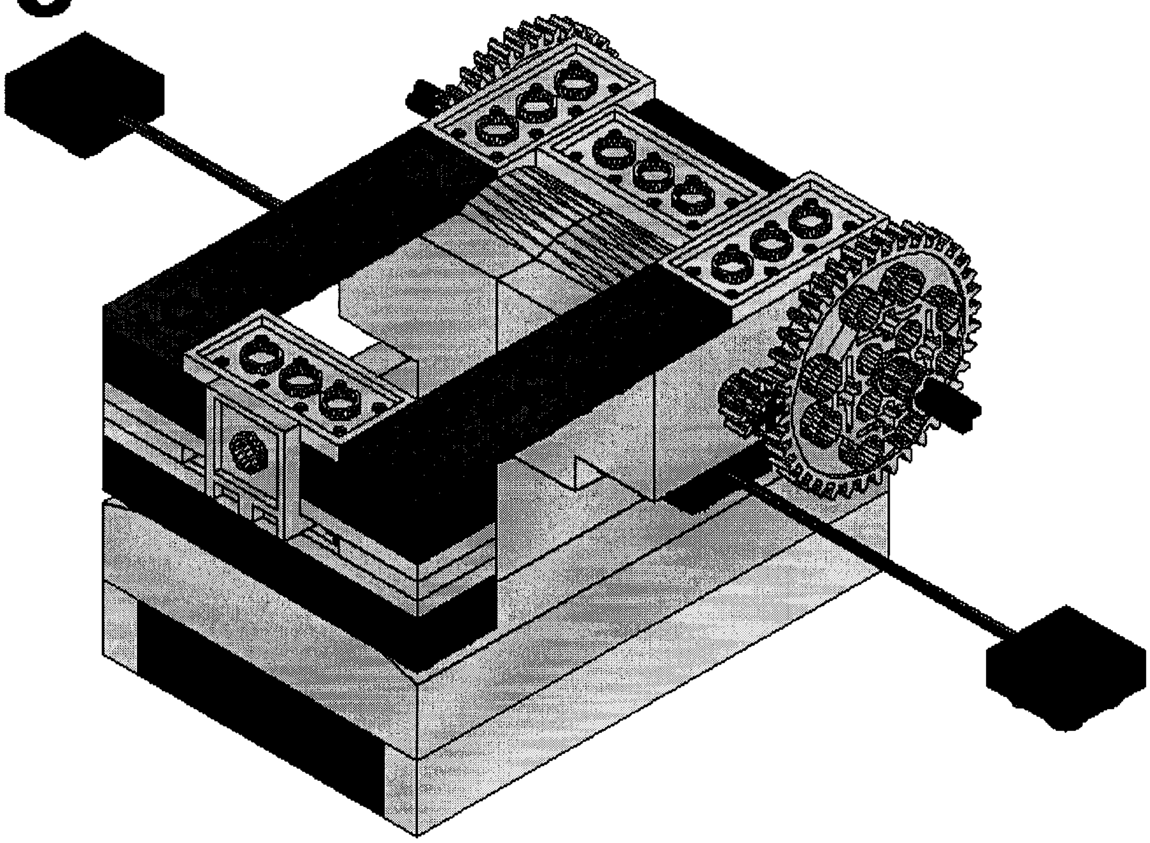

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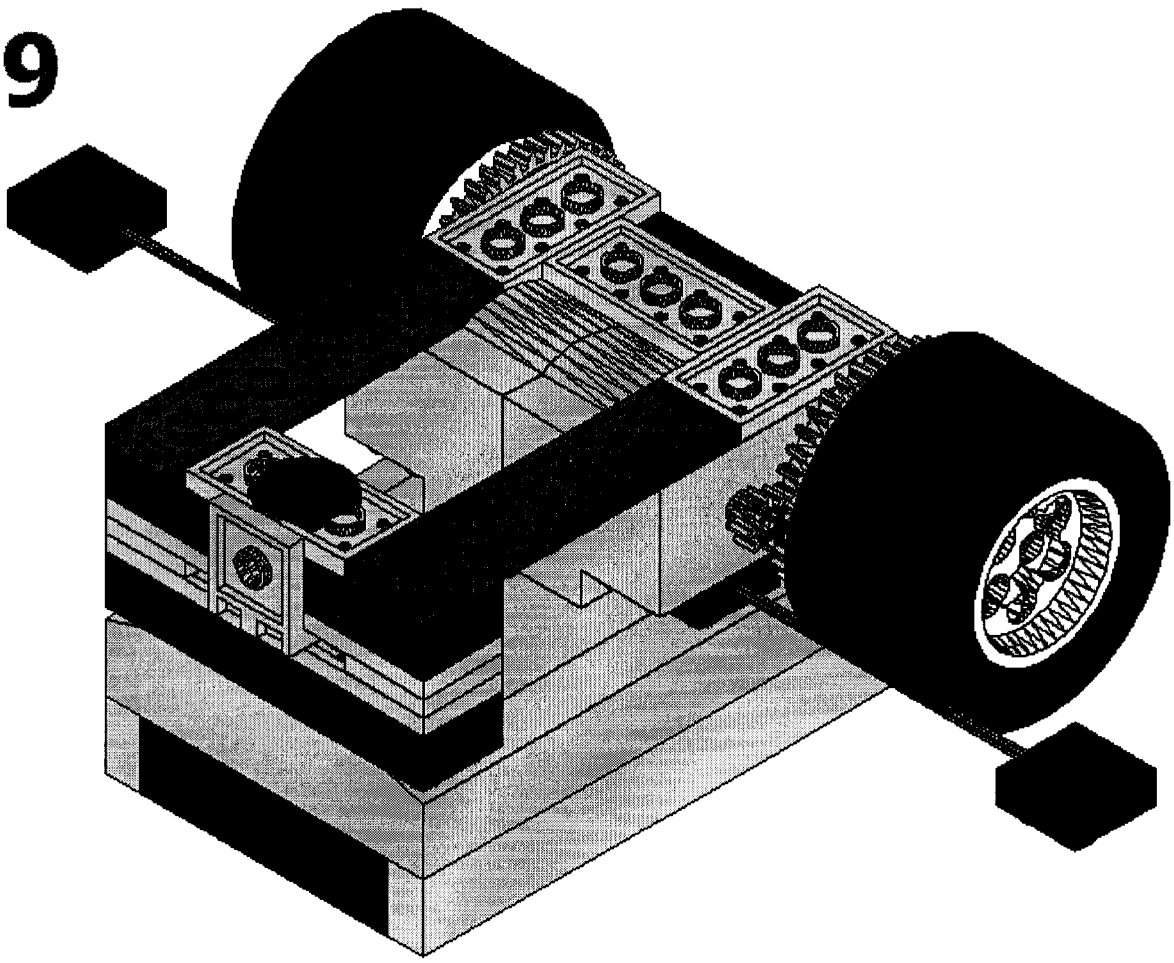

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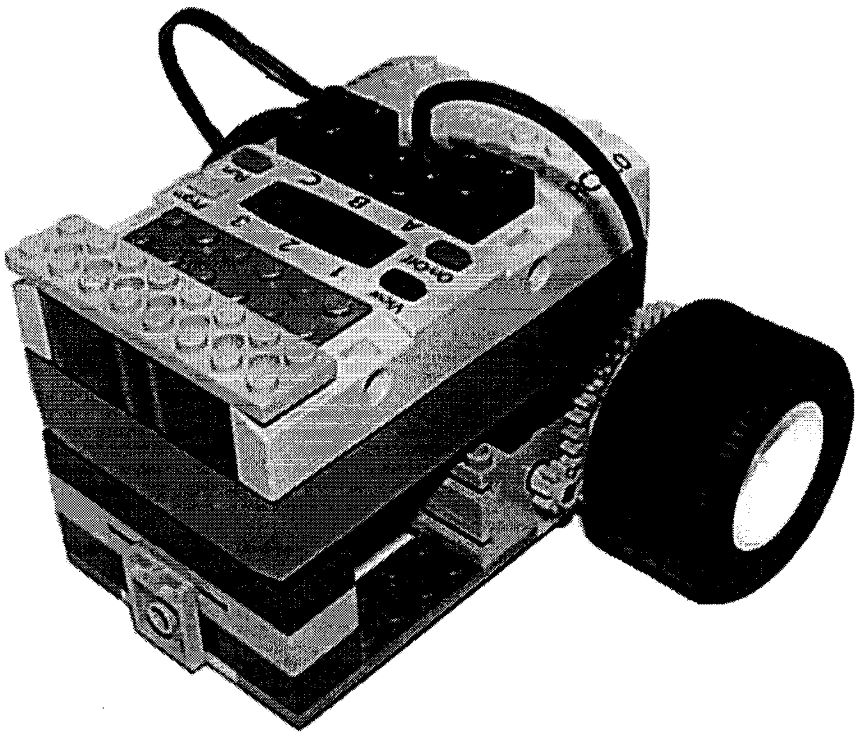
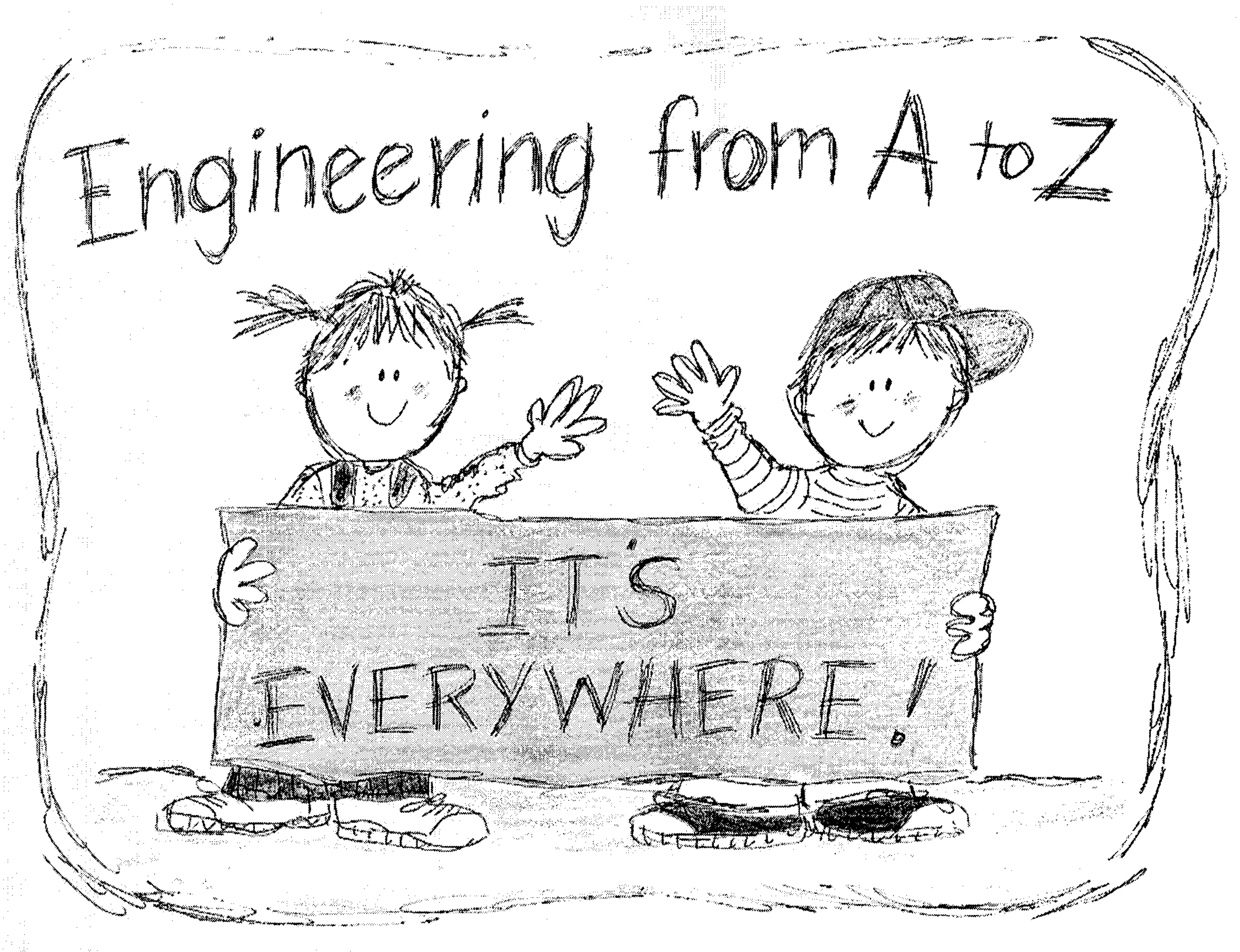
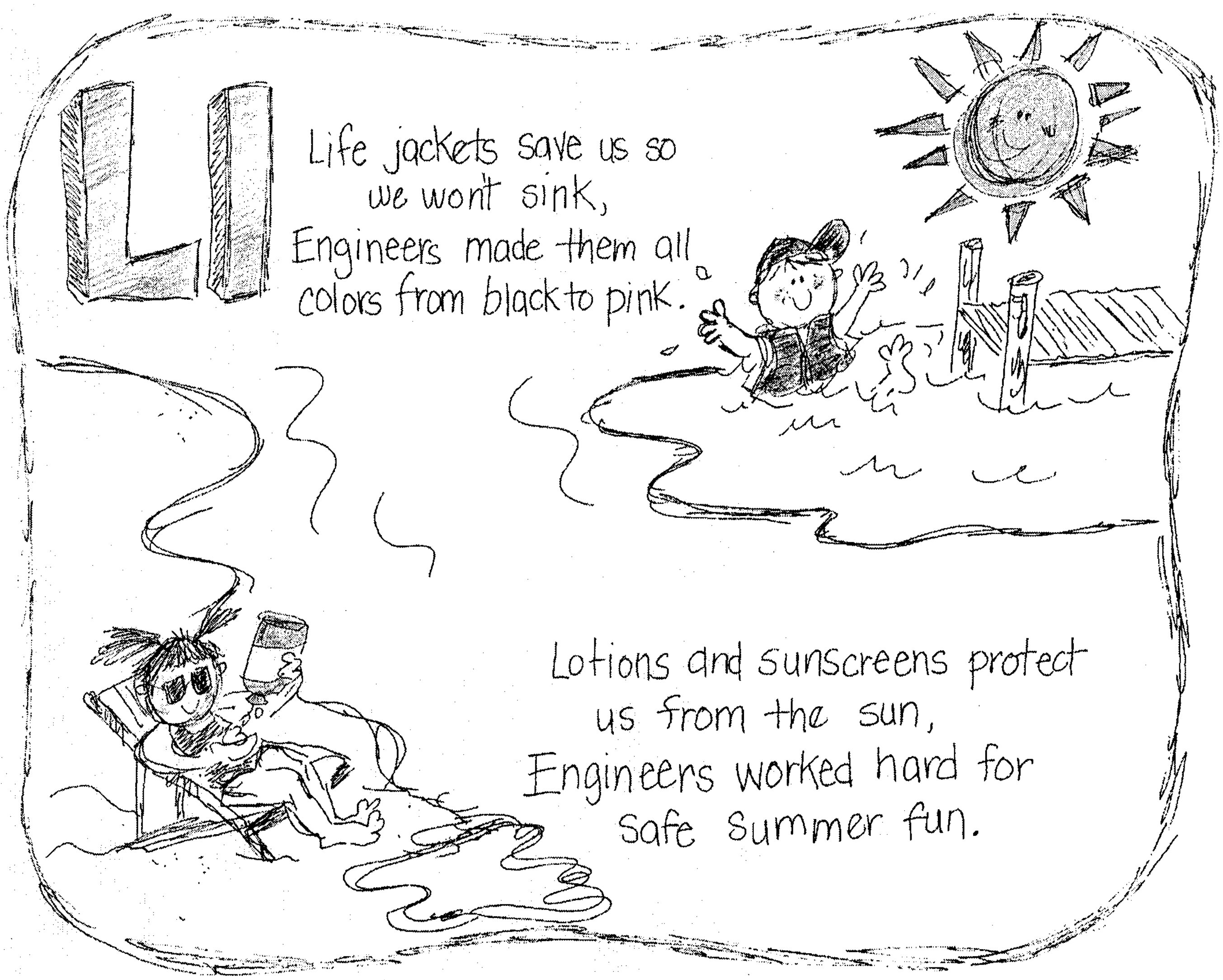
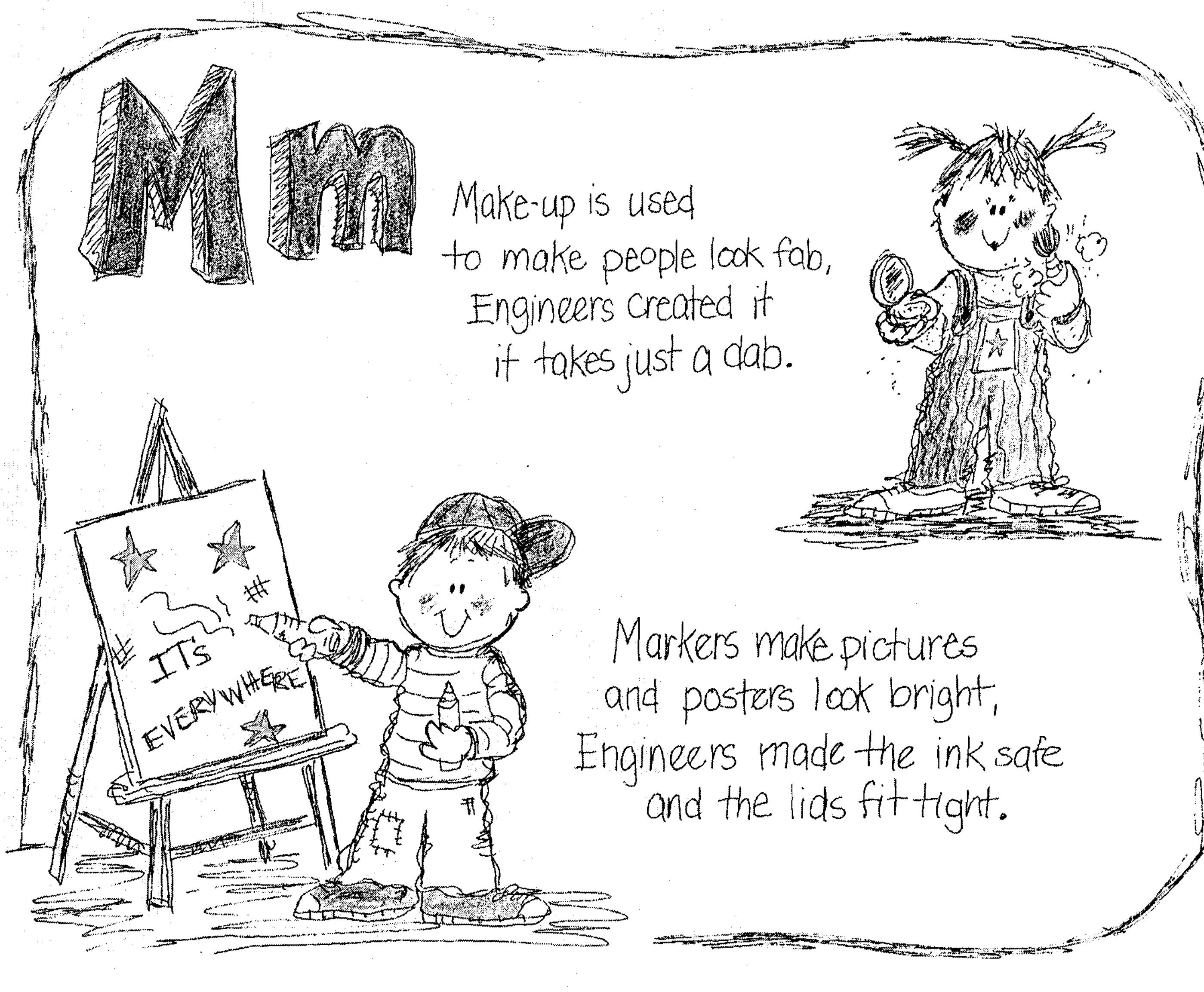


APPENDIX H. ENGINEERING ABC BOOK


Engineering from A to Z
IT'S
EVERYWHERE!


Ll
Life jackets save us so we won't sink,
Engineers made them all colors from black to pink.
Lotions and sunscreens protect us from the sun,
Engineers worked hard for safe summer fun.


Mm
Make-up is used
to make people look fab,
Engineers created it
it takes just a dab.
IT's EVERYWHERE
Markers make pictures
and posters look bright,
Engineers made the ink safe
and the lids fit tight.

APPENDIX I. POWERPOINT SLIDES

Has strong morals and values and sticks to those through her friends and her teaching

Walking buddy

You'll be a great teacher

You're one of the best friends I could ever have!!

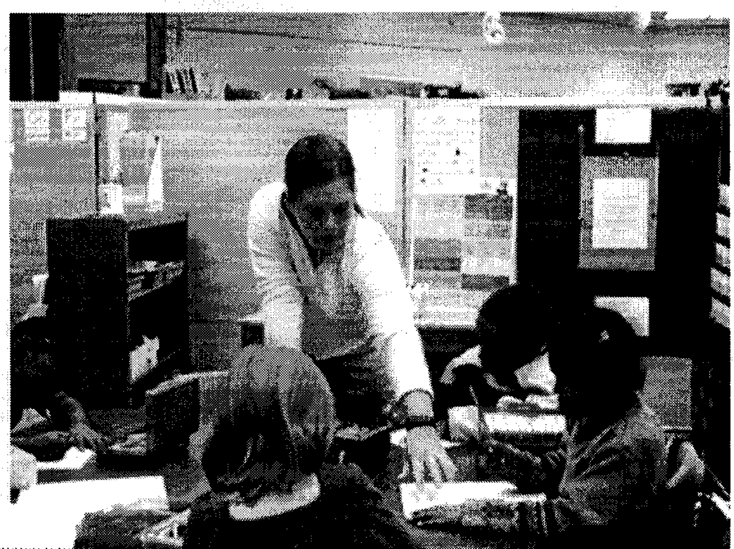
Loves to laugh with kids

Great sense of humor

Many good ideas

Stress reliever

Norwegian companion



Funny

Math girl

Quirky

DOTS

Smart

Engineering A to Z
(book published)

Many successes in her life

In tune with what she wants to accomplish in life

Your insights on things allowed me to always look at things in a new perspective

Great person to work with on group projects

A great sense o humor with kids

Engineering A to Z
(book published)

Your humor could always bring a stressful situation back down to reality

Committed

Marge

Hilarious

Makes me laugh

Responsible

Productive

Good friend

Very flexible

My stress reliever

Full of interesting and wonderful stories

From playing the recorder to being my SpEd buddy, I love you!

Huge heart that makes people laugh

You always kept all the instructors on their toes.

Great to talk to

Many Interests

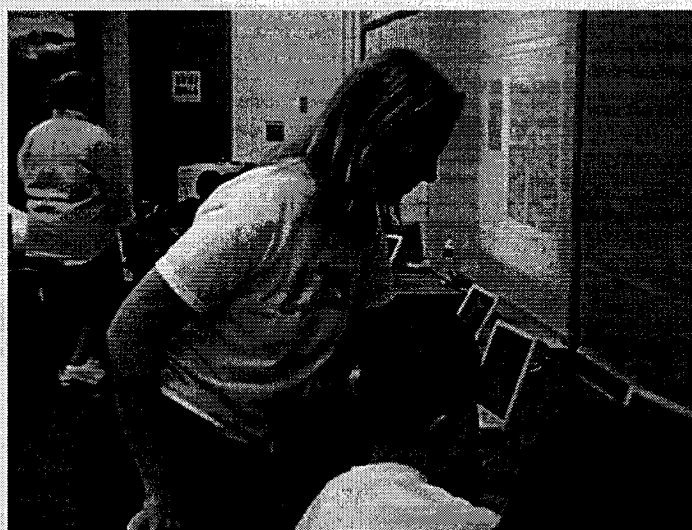
Work hard on assignments

Funny

Thoughtful

Scientific

Inquisitive



Responsible

Listener

Good friend

Committed

Hard Working

Target! I always see her there

Our Harry Potter Golf Course was the best!!

APPENDIX J. ENGINEERING ACTIVITY PHOTOGRAPHS