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The Effect of Inquiry-Based Learning in a Technical Classroom: The Impact on Student Learning and Attitude

Ian R. Hartman
Brigham Young University - Provo

THE EFFECT OF INQUIRY-BASED INSTRUCTION IN A TECHNICAL CLASSROOM: THE IMPACT ON STUDENT LEARNING AND ATTITUDE

by

Ian R. Hartman

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GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Ian R. Hartman

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	Val D. Hawks, Chair
Date	A. Brent Strong
Date	Carol Ward

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Ian R. Hartman in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

Date	Val D. Hawks Chair, Graduate Committee

Accepted for the Department

Barry M. Lunt
Graduate Coordinator, School of Technology

Accepted for the College

Alan R. Parkinson
Dean, Ira A. Fulton College of Engineering and Technology

ABSTRACT

THE EFFECT OF INQUIRY-BASED INSTRUCTION IN A TECHNICAL CLASSROOM: THE IMPACT ON STUDENT LEARNING AND ATTITUDE

Ian R. Hartman

School of Technology

Master of Science

This study investigated the effect of inquiry-based instruction in technical undergraduate education. Specifically, the effect was measured along two dimensions: 1) the effect on student learning and, 2) student attitude towards subject matter. The researcher designed an inquiry-based instructional approach to encourage interaction between teacher and students and to help students take more responsibility for their learning. Three technical undergraduate classes participated in the study. Each class was divided into experimental and control groups. For the experimental group, a twice-a-week traditional lecture was replaced with a once-a-week inquiry-based question and answer session. Students in the control group were taught as normal, by a traditional

style lecture. Students in the experimental group were expected to use the extra hour, gained by meeting only once once-a-week, to study and prepare. Both groups were administered pre- and post- tests to determine the learning that took place during the experimental intervention.   Pre- and post- surveys were also administered to assess the effect of the inquiry-based instruction on student attitude. Additionally, scores from student exams, professor surveys, and researcher observations were used to collect data and understand the effect of the instructional approach. The findings suggest that inquiry-based learning in technical classes can have a positive effect on learning and attitude.

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CHAPTER 1: INTRODUCTION

1.1. Background

> "Tell me and I forget, show me and I remember, involve me and I understand."
> —Unknown

We now live in a period of time that has been coined the information age. Never before in the history of the earth has access to information been so simple and so widespread (Yergin, 2002). In years past, superior access to raw materials, labor, and manufacturing practices was the impetus for competitive advantage. Current trends in socioeconomic development suggest a new reliance on professional and managerial staff with advanced training, and higher education (Cabal, 1993). Companies in every industry need employees who can locate, interpret, and transform information into knowledge and understanding.

In the face of foreign competition educators are increasingly looking for means whereby they might enhance the learning experience in American universities. No longer are graduates from American universities protected from overseas competition as in years past. The New York Times Magazine reports that, "several hundred thousand U.S. tax returns are being prepared every year in India; CAT scans from American hospitals are being analyzed by doctors in Australia; scientists in China are doing research for Microsoft; Russian engineers are working on aircraft design for Boeing" (Friedman, 2005, as quoted in Bok, 2006, p.5). In response to this increased competition, the Accreditation Board for Engineering and Technology, as well as the American Society of

Engineering Education and the National Academy of Engineering, have called for American universities to modify their teaching paradigms (Bok, 2006 p. 299). In order for US students to compete globally they must improve their capabilities in communication, ethnic sensitivity, ability to collaborate, cultural awareness and understanding of the sociopolitical environment (Bok, 2006, p. 299). Simply stated, they must be more knowledgeable and better able to adapt to and understand the dynamic world we live in.

Traditionally, institutions of higher education have performed superbly in the realm of factual transfer. A study performed at the University of Illinois found that 82 percent of students reported that most of their grades were based on the memorization and regurgitation of factual information (Milton, 1982). One explanation for this phenomenon is the rigorous amount of information instructors are required to cover in their curriculum. This pressure to cover material has led many professors to espouse a lecture-based approach to instruction.

Lecture-based instruction is the predominant mode of teaching in American universities. This approach centers around a lecture where the professor summarizes, highlights and reinforces important information from pre-assigned readings. According to a study conducted by Courts and McInerny (1993), an over reliance on lecture and textbook exercises was a common concern voiced by students regarding in-class instruction. What students want is more interaction and more “hands-on learning” (p. 33-38).

In order to create the type of well rounded graduate industry and the accreditation boards are asking for, new teaching methods must be considered. Lecture-based instruction often has difficulty attaining significant levels of deep understanding. This is because lecture-based instruction promotes memorization of facts and principles, and primarily focuses on surface learning. It often fails to delve deep into subject matter creating knowledge students can practically apply.

Recently some educators have turned to inquiry-based models in their classrooms in an attempt to deliver a richer learning experience for their students. The National Science Education Standards (National Research Council, 1996) state, “Teaching must involve students in inquiry-oriented investigations in which they interact with their teachers and peers. Students…engage in problem solving, planning, decision making, and group discussions” (p. 20). Inquiry-based learning is a student-centered, active learning approach that encourages critical thinking and problem-solving. An inquiry-based approach often results in course material being delivered through class discussions, collaborative projects, and other active learning tasks. This structure encourages students to think for themselves and to question how subject matter is interrelated with other subjects. This active mode of learning appears to be very promising in its abilities to help students attain higher levels of knowledge and understanding (Chang, 1999, Felder, 1997, Jones, 2003).

1.2. Problem Statement

Apparent deficiencies in prevalent teaching formats present an opportunity to explore new methods. This thesis has been undertaken in an effort to determine if a new approach can be implemented to enhance student achievement in technical undergraduate course work.

The study seeks to determine if a deeper understanding can be taught by replacing the traditional lecture-based instruction with an inquiry-based format emphasizing a question and answer session focused on pre-assigned readings. Traditional classes are typically teacher oriented, with the teacher dispensing information to the students. Lectures are generally a review of pre-assigned readings and students have little opportunity to ask questions or learn how the subject-matter is interrelated with other material and adjacent areas of study.

If students are unable to learn the relatedness of course material to other areas they will struggle to span disconnects within their knowledge frameworks. Espousing a traditional lecture approach limits teachers in their ability to identify and address such gaps in their students' understanding. Lasting knowledge is formed when gaps in understanding can be connected or bridged to other areas of existing knowledge. The brain is not adept at retaining odd facts and pieces of information unless they are integrated into a knowledge framework to enhance their contextual meaning. Jensen (2005) states "finding out what students know and asking them to make connections to another, more accurate model is how the real learning process begins" (p. 47). The traditional lecture is very teacher centered, and determining where students' knowledge is lacking can be difficult.

The primary question this research seeks to answer is: What would happen if instead of following a lecture-driven format, one prepared by the professor, the class lecture was directed primarily by student questions relating to pre-assigned readings? This type of a classroom format would eliminate the need for teachers to anticipate students’ disconnects and would help students to identify them on their own. It would allow students to learn about the course content they find most interesting, as indicated by their questions, while at the same time allow the teacher to expand learning and stress important implications and applications of the subject matter. The inquiry-based system also allows students to be much more involved in the teaching of the course and encourages them to take more responsibility for learning. More importantly, it should foster greater interest, and when students become interested in a subject, learning occurs without much assistance from the instructor (Wurdinger, 2005). After this happens the instructor can guide the students through the learning process, providing information and resources as needed. The question this thesis seeks to answer is whether an inquiry-based format, tailored as a question and answer session, can help students and teachers develop an atmosphere where students learn better and foster better attitudes towards the subject matter than is achieved in classrooms taught using a traditional lecture.

1.3. Purpose of the Study

The purpose of this study is to determine if increasing student involvement in the creation of teaching content, facilitated by an inquiry-based question and answer session, can improve learning in technical undergraduate courses. This improved learning will be measured according to two criteria. First, can an inquiry-based question and answer session improve learning over a traditional lecture in a technical class? And second, can an inquiry-based question and answer session enhance student attitudes towards the subject matter as compared to a traditional lecture in a technical class?

1.4. Significance of the Study

If learning is improved through inquiry-based classes, then many educators and students could benefit by using this teaching method in technical oriented classes. The quality of our education system would improve, thus producing graduates who are better prepared to compete and contribute in the competitive global economy of today.

1.5. Hypothesis

Research question 1:

Is there a difference in student learning related to the use of traditional lecture or inquiry-based instructional methods in technical classes?

The null hypothesis is then stated as follows:

$1H_o$: There is no difference in learning among students experiencing traditional lecture compared to inquiry-based instruction in technical classes.

Research question 2:

Is there a difference in student attitude towards course material related to the use of traditional lecture or inquiry-based instructional methods in technical classes?

The null hypothesis is then stated as follows:

$2H_o$: There is no difference in attitudes among students experiencing traditional lecture compared to inquiry-based instruction in technical classes.

1.6. Methodology

In order to determine the relative levels of learning achieved through an inquiry-based question and answer driven class and a traditional lecture, three undergraduate courses within the School of Technology will be selected to participate in this study.

Each course will be divided into two groups; a control group and an experimental group. The control group will be taught using a traditional lecture, the experimental group using an inquiry-based question and answer driven system. Identical measures will be applied to the two groups. Observations will be recorded, analyzed, and finally, conclusions will be drawn.

1.7. Delimitations

The purpose of this research is not to determine if an inquiry-based question and answer driven system should replace the traditional lecture, but to determine if it can enhance and improve learning. This study is also limited to a duration of four to five weeks. Because of the length of the study it will be somewhat difficult to predict the effects of the inquiry-based instruction over extended periods. Also, this study has been constrained to courses dealing with technical subject matter, and the results may not be valid for other types of classes. This study is not intended to demonstrate or determine the best measure of learning.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

In the world there are three types of people: Innovators, implementers, and slugs. The innovators are the people who invent things. They are creative and often think outside the box. Implementers are the workers – they are the people who get things done. They are the ones who are given a task or an assignment and they have the skills to make it happen. Then, there are the slugs – they contribute little. They lack significant creativity or capability.

The American educational system has historically focused on creating an environment conducive to the needs of innovators. There is no question that some of the most important modern day inventions have originated in the United States. Many would argue that part of the reason that so much innovation comes out of the U.S. is that our educational system encourages breadth. Graduates from our universities typically have knowledge about a broad range of disciplines, however, often only at a surface level. This breadth of knowledge is what uniquely positions them to have valuable insight and creativity as they approach problems. However, as our economy becomes more technologically advanced, it has become more difficult to innovate without more specialized knowledge.

In contrast to the American trend of providing breadth of knowledge, the trend in other parts of the world is to focus on depth. Students in American schools achieve limited depth in their undergraduate experience. Depth is usually attained at the graduate level (Ward, 2007). In many European and Asian countries, depth or specialization occurs much earlier. For example, in Europe it is common for children to begin specializing during their adolescent years. Children who demonstrate an aptitude for math and science are selected for a curriculum that is heavily oriented towards professions as engineers or scientists. This approach to education in essence has created a graduate that is highly specialized and highly skilled (albeit narrowly). As globalization has created a much "smaller" world, competition for jobs requiring specialized training has become more pronounced. As this has occurred, American undergraduate students have begun to find themselves facing increased pressure.

Because the competition for jobs has become more intense, there has emerged a sense of urgency within the American educational system to improve the way we teach. Flynn (1995) states, "We are told that the United States faces crisis in global competition and that if we do not do a better job of preparing our children for the new world order we will lose our preeminent economic status. Teachers are thus instructed to better prepare students for the new world of work" (p.53).

In order for American students to be more competitive in the world job market they need to have more depth of knowledge. This does not necessarily mean earlier specialization. Nor does it mean that breadth should not be taught. Having a large knowledge base helps students understand the world and how different disciplines or knowledge areas interrelate. The greatest challenge these students face is that the global economy demands highly specialized skills in many of the technical areas. The challenge, then, for educators is how teaching can be modified or improved to add more depth to the learning experience at the undergraduate level.

Throughout modern history researchers and academics have earnestly sought to better understand and improve teaching and learning practices. Such efforts have yielded a vast body of knowledge regarding learning and teaching methods. The National Research Council published a book entitled "How People Learn: Bridging Research and Practice" (Donovan, et al., 1999) which consolidates much of what is known about teaching techniques. The authors suggest most modes of teaching belong to five main methods: Lecture based, technology enhanced, individual vs. group, inquiry based, and skills based. Figure 1 shows these groups and a few of their respective techniques.

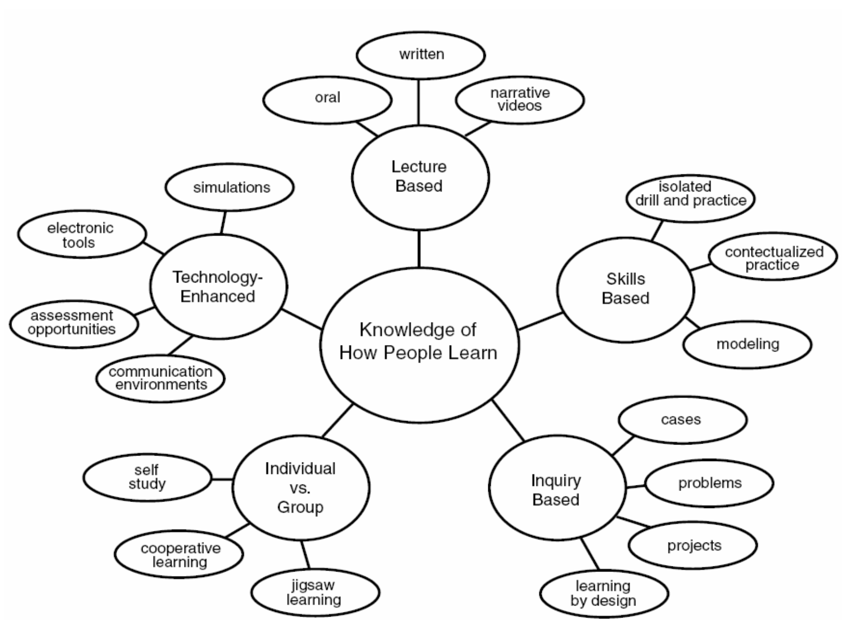

Figure 1: Types of Learning (Donovan et.al. 1999)

Although in the figure above it appears that each learning mode has clear distinctions, the lines between each of these techniques are quite fuzzy. For example, inquiry based teaching can be used in conjunction with technology enhanced learning, or skills based teaching can be conducted at an individual or group level. The intent of the figure is to demonstrate the various families and their corresponding tenants.

The present study will focus mainly in the areas of lecture- and inquiry-based methods. The intent of the study is to determine if an inquiry based approach to teaching in a technical environment can improve learning as opposed to a traditional lecture approach. The intent is not to determine whether specialization should occur earlier, or whether less breadth should be taught. It is only to determine whether inquiry learning can help improve or deepen the learning that takes place in technical undergraduate classrooms.

In order to establish the legitimacy of this research undertaking, and to better understand the body of knowledge relating to this topic, a review of literature was conducted. This review covers four main areas. These areas are: Learning theory, traditional teaching methods, inquiry based teaching, and finally, the effect of discussion on learning

2.2. Learning Theory

2.2.1. Introduction

In this section we will cover two very prevalent and influential theories of learning. Our discussion will first cover an area of learning theory known as constructivist learning theory. Through this theory, scholars have attempted to explain how learning takes place. Constructivism is a well accepted theory, which is heavily influenced by cognitive development theory and suggests that as people learn they construct a framework through which they interpret and give meaning to knowledge and information. A more recent theory mastery theory, will be presented. This theory, developed by Benjamin Bloom, proposes that if teachers customize instruction for the individual needs of each learner, a mastery level of understanding can be achieved.

2.2.2. Constructivist Learning Theory

Most modern day learning theories, including constructivism, have been influenced by two schools of thought, Vygotsky in Eastern Europe and Piaget in the West. According to Piaget (Jarvis 2003), learning was directly related to the different stages of cognitive development. He proposed that cognitive development could be decomposed into five stages. These stages are: Sensori-motor, pre-operational thought, intuitive, concrete operations, and formal operations.

Table 2-1: Stages of Cognitive Development (Jarvis, 2003, p.33)

Stage	Age	Characteristics
Sensori-motor	0-2	Infant learns to differentiate between self and objects in external world
Pre-operational thought	2-4	Child ego-centric but classifies by single salient features
Intuitive	4-7	Child thinks in classifactory way, but may be unaware of classifications
Concrete operations	7-11	Child able to use logical operations such as reversibility, classification and serialization
Formal operations	11-15	Trial steps towards abstract conceptualization occurs

According to Piaget's learning theory, as is evident in Table 2-1, the ability to conceptualize forms as one get older. The pinnacle of Piaget's theory is the formal operations stage. In this stage a person's thinking is abstract, rigorous, and logical. Piaget suggested that a student's ability to understand or assimilate new information is dependent on the preexistence of a knowledge structure (Brynes, 1996). This knowledge structure can be thought of as a framework that is built over time, where information is placed to create links to related information and ideas. Often an idea or information is so dramatically different from current knowledge within the framework that students have difficulty assimilating it. When this happens, the new idea must be accommodated by reorganizing existing knowledge structures. In this manner, misconceptions or false beliefs are displaced with more accurate information.

According to research by Piaget, confronting conflicting or discrepant ideas is essential for knowledge growth (Brynes, 1996). For example, children often construct false beliefs as they mature. If they never encounter ideas to challenge these false notions, they will struggle to develop accurate understandings.

Vygotsky's theory somewhat challenges Piaget's belief that cognitive development must precede higher level thought (Brynes, 1996). Like Piaget, he did believe in a relationship between the developmental process and learning capabilities. Where he differed from Piaget was his theory of actual development and zone of proximal development (Brynes, 1996). As might be inferred, actual development is based on age or the physical development stages. Alternatively, the zone of proximal development is the level of thought an individual can achieve when coached by someone of superior capability (Brynes, 1996). Vygotsky believed that with the assistance of a more competent individual, a person could exhibit higher levels of thought than actual developmental stages might suggest. This theory connotes the important role teachers play as they interact, encourage and give feedback to students.

In Vygotsky's theory the interaction between students and teacher is extremely important. In fact, according to Vygotsky if a skill is not acquired with the help of a more competent person, a teacher, it should not be considered high level thought.

According to Vygotsky, “social interaction is the key to shifting a skill from the lower-order version to the higher-order version” (Byrnes, 1996, p. 65).

Like Vygotsky, many scholars in the field of education have discussed the importance of teacher-student interaction in the learning environment. Learning is more than an assimilation of facts and information. “Learning is…a way of interacting with the world” (Biggs, 1999, p.13). Biggs (1999) states that through learning, students’ notions of the world change and adapt. This change is brought about not by the information itself, but in how the information is structured, and how it is used. As students interact with teachers, a better understanding of how to use and apply course material and concepts is achieved.

Constructivist learning theory is founded upon the belief that learning is a dynamic process. As students learn their knowledge is in a state of constant flux. New knowledge is created upon an existing knowledge structure, and the addition of new blocks of information can alter the way previously learned information is used and interpreted. A fundamental tenet of constructivism is the notion that learners do not absorb information, instead, they construct it through their experiences. Tobin and Tippins (1993) assert that teachers need to focus their classroom efforts in two main areas. “First, what experiences should be provided to the learner in order to facilitate learning; and second, how can the learner represent what is known already to give meaning to these experiences” (p. 9). Teachers can be more in tune with the needs of their students if they will foster a classroom environment where students are comfortable and encouraged to ask questions. When they are in tune they can effectively tailor their instruction in a manner that will provide for the fulfilling of both these objectives. For teachers to be most effective, they must understand what their pupils already know.

Tobins and Tippins (1993) also stress the idea that a teacher's role is to mediate the learning process. This has important implications for how teachers approach instruction. Far too often teachers focus on content coverage and are less concerned with the extent to which students have grasped the material. To be an effective mediator, teachers must interact with students to a greater extent than is often done in traditional classrooms. Donovan et. al (1999) also stress the importance of educators being student centered and being facilitators of learning, not presenters of information. When this is accomplished, interaction occurs on an individual level allowing teachers to ascertain what the students know and what they are thinking (Tobin 1993). As part of their mediation efforts teachers should also provide opportunities for students to demonstrate understanding and to assist in answering peer questions. When students are required to put knowledge and learning into words, they become aware of the areas where their understanding is incomplete; and, as Piaget taught, they are then able to connect new information to existing knowledge.

2.2.3. Mastery Learning Theory

Another renowned scholar in the area of educational research is Benjamin Bloom. Bloom (1976) hypothesized that if a normally distributed group of students with respect to aptitude are given identical instruction, that the measured achievement of those students will also be normally distributed. However, if a normally distributed group of students with respect to aptitude is given instruction that is appropriate to each individual's needs, then the majority of the group will achieve mastery of the subject matter. Bloom believed quality of instruction and time allowed for learning to be the determining factors relating to mastery. This theory was tested in many studies conducted throughout the 1970's and 1980's producing considerable evidence that mastery learning procedures do work. Typically, 80% of students were able to achieve mastery levels of learning (Bloom, 1976, p. 5). Bloom stressed the importance of identifying instructional objectives, administering intermittent learning assessments, providing feedback, following up in areas of weakness, and a final learning assessment. Bloom's assessment and feedback mechanism serves as a corrective loop that helps students and teachers to monitor progress and make adjustments as necessary. This on-the-fly adjustment is what makes it possible to help the majority of students achieve a mastery level.

Bloom believed the largest determining factor contributing to student achievement was quality of instruction. According to Bloom, quality of instruction could be defined along four dimensions—cues or directions provided to the learner, participation of the learner in the learning activity, reinforcement relating to learning objectives, and feedback or correction.

Cues give structure and direction to learning tasks. They can be thought of as the vehicle by which learning content is transferred or conveyed. In most classroom settings, they are verbal but can take several different forms. Some may be visual stimuli that prompt a specific response, such as a demonstration which students are to reproduce, i.e. a mathematical model or graph (Bloom, 1976). Cues may also utilize other senses, such as touch or smell. If a cue is familiar and has been encountered or used before it is often much more powerful. The most important thing to understand about cues is that not every student responds to each cue in the same manner. If a class is taught using primarily verbal cues then the students who respond well to verbal cues will excel while others may flounder. To be most effective, teachers should know how their students respond best, and tailor instruction to reach as many students as possible. This should also include considerations of cultural, social, and other individual backgrounds.

Cues must be acted upon in order for learning to occur. Bloom (1976) suggests that some form of involvement of the learner is required if learning is to take place. Teachers are faced with the task of delivering instruction (cues) in a manner that encourages student participation. This task often involves creating strategies and activities intended to promote participation. In small settings, teachers can set aside time to spend with each student individually; in larger groups, teachers may split the class into smaller groups where individuals are required to do something observable by others in the group. Collecting oral and/or written assignments is a method often used to ensure student participation in learning activities.

Like most learning theories, the mastery approach utilizes reinforcement schemes. Reinforcement has long been recognized as an important tool for teachers to use. Most teachers use some form of reinforcement during and after learning. However, the type, the form, and the frequency vary greatly. Reinforcements can be negative or positive. They can play to basic needs like food and warmth, or they can be learned. Social approval of peers and teachers is an example of a learned reinforcement – it is often a very strong reinforcement in academic settings.

Bloom (1976) proposes that some students might not achieve their potential because teachers have not learned to properly reinforce them. “Reinforcements are likely to be differently perceived by students and … the teacher who operates with a limited amount and variety of reinforcements may not be adequately reinforcing some of the students in the class" (Bloom, 1976, p. 120). As the amount of interaction between student and teacher increases, teachers will be better equipped to reinforce students in the manner they best respond to.

In the sciences, it is often believed that if something is not measured, it cannot be improved. Such is the purpose of correction and feedback within the mastery learning approach. It enables students to be apprised of their understanding and progress in a real-time fashion. Teachers give students feedback in order to help students focus their efforts in the area(s) where they need additional instruction and practice. If students are not aware and appraised of their performance in specific areas they will not seek out additional opportunities to learn the material. The amount of time and practice needed in order to develop a mastery level of a specific subject matter varies greatly from student to student. Feedback helps identify which students need additional time and coaching to attain achievement goals.

2.2.4. Summary

When viewed from the perspective of constructivism, there appears to be many opportunities to enhance the learning experience in technical courses. Teachers should encourage increased interaction in order to help students identify and remedy their false notions or beliefs relating to the subject matter. Increased interaction with the teacher (someone of superior capability), as suggested by Vygotsky, will also help students attain higher order or deeper learning.

From the discussion of mastery learning, the importance of timely feedback and corrective loop mechanisms was stressed. Teachers must also be cognizant that all students do not respond the same way to each teaching method. Teachers who are flexible and can use a variety of cues will reach a greater number of their students. In order to be in-tune with which cues are working, teachers need to engage in dialogue with their students. Another important concept from the mastery approach is the need for reinforcement. Reinforcement helps to solidify correct learning, and deter the acquisition of incorrect understanding.

2.3. Traditional Lecture

The preceding section was devoted to a discussion of learning theory. It addressed many well accepted views on how learning takes place, as well as several considerations that should be thought about as educators develop teaching strategies. This section will address the traditional lecture style. Despite all we know about learning and how best to create and foster healthy learning environments, the lecture approach to teaching remains a common practice at the university level.

In the American higher education system, the predominant mode of teaching follows a lecture format. In a lecture format the teacher is tasked with dispensing information and the learner or student is tasked with memorization of that information. Most often, instruction revolves around material from a textbook. The teacher usually summarizes information, and offers explanations and insight along the way. This mode of teaching is often very one-sided, and without teacher encouragement affords little opportunity for student involvement. Lectures are often, but not always, supplemented with assignments or homework problems to be completed outside of class.

A major deficiency related to the traditional lecture is the passive role played by the students (Martin, et. al., 2002). Bok (2006) states “lectures demand little of [students] except sitting still. No preparation for class is necessary” (p. 125). This trend in our educational institutions detracts greatly from the learning experience. Felder (2006) suggests that lectures play little role in whether the brightest students will learn. Good lectures may enrich their experience, but they will learn regardless of whether they receive quality instruction. However, as university education has become available to a broader segment of the population, there is now a demand for instruction that will reach a larger more diverse group of students. According to Felder (2006), the traditional lecture is an insufficient means for teaching large diverse groups. The fact that many engineering programs experience more than 50% attrition is good evidence that current instructional methods are falling short (Felder, 2006).

At the university level it is believed that when students complete technical courses they will have gained an increased ability to problem solve and to think critically about the environments they experience. However, the traditional lecture-recitation classroom fosters primarily memorization. It does not teach students to ask the right questions, or to gather information needed to make a decision or analyze a problem. The traditional lecture focuses on giving out learning, not teaching how to learn.

The Chinese proverb, “give a man a fish and he will eat for a day, teach a man to fish and he will eat for a lifetime,” is an appropriate analogy for what often is, and what should be, accomplished in the classroom. Traditional lectures are very efficient at giving out fish, but sometimes fall short of teaching to fish. Because the world we live in is changing so fast, it is imperative that students learn how to learn. Much of what we learn in school will soon be obsolete. Those who have learned to learn and who can quickly adapt to the changing environment will have an advantage in the workplace. To be successful, students must be able to develop new innovative solutions to problems. This will require skill in the areas of problem-solving and critical thinking.

2.4. Inquiry Based Learning

Now that a framework has been constructed delineating learning theory, and the traditional lecture, it is appropriate to introduce the mode of learning which has become the subject of this study – inquiry learning. As defined by Hebrank (2000), inquiry learning is a method of attaining knowledge through the process of inquiry. “In inquiry-based learning, students either ask their own questions or are posed a question by the teacher. In the former case the question concerns a topic the students wish to learn about, and in the latter case the question concerns a topic the teacher wishes students to learn about. Regardless of the source of the question, inquiry-based learning requires that students play a major role in answering the question” (Hebrank, 2000). Inquiry-based learning offers unique advantages, because it allows the students to take a more active role in defining classroom discussion. It is a teaching method that fosters communication and collaboration between teacher and student. Although discussion topics are often initiated through students questions, teachers should dictate, through the careful selection of course readings and materials, the direction and pathway the course will take. This approach allows a broad gamut of topics to be discussed and integrated into the curriculum based upon the disposition of the student. Through the careful selection of material, teachers can provoke meaningful inquiry and discussion from the students. The selection of material can also help steer the questions in the direction the teacher deems most appropriate.

Zevin (1973) pointed out that inquiry teaching creates an atmosphere where students are encouraged to think, and to solve problems. It fosters skillful questioning, and the use of questions that allow for more than one answer. He also characterized inquiry classrooms by attitudes and behaviors stressing:

1. free and open discussions of values and issues;
2. encouragement and praise for the expression of ideas;
3. extensive use of student ideas;
4. questioning by both teacher and students, with a high proportion of questions falling into the upper cognitive levels, i.e., questions that call for analysis synthesis, and evaluation, and;
5. wide and frequent student participation. (Zevin, 1973, p.311)

Grabe and Grabe (2000) define inquiry-based learning in the following manner:

> Inquiry involves finding sources of information appropriate to a task, working to understand the information resources and how they relate to the task, and then, in those cases for which some action is expected, applying this understanding in a productive way. (p.21)

This definition stresses one very important facet of inquiry-based learning – that of translating information into actionable knowledge. Far too often students finish courses only to have acquired a set of new facts and information. What they lack is the ability to profitably apply what they learned. According to DiPasquale, et al. (2003), inquiry-based learning can teach students analytical and critical thinking skills. Analytical skills are important as they help students to determine trends in data and similarities or differences among variables. Critical thinking skills are the pinnacle of the learning experience. It is at this point that students begin to understand the interrelatedness of different disciplines and can often draw from knowledge of ancillary subject matter to enlighten their own understanding.

Inquiry learning falls into a broader category of learning often called active learning. Active learning, as the name suggests, requires activity on the part of the student. Biggs (1999) presents data in Table 2-2 suggesting that students participating in active learning environments will learn a much larger portion of the material than those participating in less active learning environments, i.e., a traditional lecture. Active learning requires a classroom to be structured in a manner that allows student and teacher to collaboratively work together. According to the data in Table 2-2, as the degree of activity increases so too does the amount of learning. Inquiry-based learning requires students to take an active role in the learning process.

Table 2-2: Amount of Learning vs. Instructional Method (source: Association for Supervision and Curriculum Development Guide, 1988, as cited in Biggs, 1999, p.78)

Most People Learn…
10% of what they read
20% of what they hear
30% of what they see
50% of what they see and hear
70% of what they talk over with others
80% of what they use and do in real life
95% of what they teach someone else

Umar and Maswan (2004) assert that within the realm of inquiry-based learning there are three different levels. The first is *structured inquiry*. As the name suggests this is a structured approach where the question, process and procedure of inquiry is predetermined by the teacher. The second level is *guided inquiry*. This approach offers learners an amount of autonomy by allowing them to determine the procedure for discovery, however, the question is set forth by the teacher. The third and highest level of inquiry is *open inquiry*. Students experiencing open inquiry take a much more active part in the process as they are able to investigate and explore based on their own questions and the procedures they deem appropriate.

Studies have shown that inquiry-based teaching can have a dramatic effect on learning outcomes. One study (Jones, 2003) conducted in North Carolina found that inquiry-based teaching had a positive effect on students participating in an undergraduate psychical science course. The study ran over a four year period and showed that students participating in an inquiry based class demonstrated better participation, course grades, and overall achievement than did students in a traditionally-taught class (Jones, 2003). Students attending an inquiry-based class exhibited "higher attendance, were less likely to give up, and more likely so take the standardized test at the end of the course" than were students participating in a traditional class (p 348). Students in the inquiry classroom also posed fewer disruptions and exhibited less antagonistic behavior. The study demonstrated that the class as a whole attained a higher level of learning with less of an achievement gap between the top and bottom performers. However, scores reported by the inquiry group on a state-wide standardized test showed no significant difference from the traditionally taught group.

Chang and Mao (1999) conducted a study involving inquiry learning in an earth science classroom consisting of junior high students in Taiwan. The results of their study showed that inquiry had a significant effect on the achievement of those who participated.

After administering an attitudes inventory to the inquiry group as well as the control group, they noted a statistically significant improvement for the inquiry teaching methods. This is consistent with Jones' research.

Felder (1997) conducted a study to determine the effect of using alternate approaches to teaching chemistry. He used several teaching techniques that fall into the realm of inquiry teaching. His treatment groups were taught using techniques to encourage collaboration and promote the extensive use of questioning. The study consisted of five sequential courses in chemistry. From the results of the study it was not conclusive whether the experimental group performed better as far as course grades were concerned, but the results were very revealing along other dimensions. Table 2-3 is a list of some of the significant findings. Students participating in the experimental group exhibited a higher graduation rate, had greater confidence in their abilities, larger percentages thought their introductory courses had prepared them well and were more likely to pursue graduate school.

Table 2-3: Felder Results (Felder, 1997)

Question	Response	Experimental	Control
How well did ChE 205 and ChE 225 prepare you for ChE 311?	Excellent	44%	4%
How do you rate your basic problem-solving skills?	Excellent	32%	19%
How do you rate your ability to slove challenging problems?	Excellent	21%	6%
If you could do it again would you still go into ChE?	Excellent	96%	80%
Do you plan to pursue graduate study in ChE?	Excellent	18%	7%
Percentage of students who started and finished?		80%	74%

2.4.1. Implementing Inquiry: Concerns and Challenges

Although several studies have suggested that inquiry learning can be more effective than a traditional lecture, it is still not widely used in the undergraduate technical classrooms. There are several reasons professors are reluctant to incorporate aspects of inquiry learning into their classrooms. A common concern is that inquiry methods adversely affect the ability to cover large amounts of course content. Another common concern is that professors will be unprepared for the wide range of questions students will ask. But perhaps the greatest resistance to integrating more inquiry into the classroom is the tremendous inertia behind the traditional lecture approach. Not only were most professors taught by the traditional lecture, but it has been used in higher education for hundreds of years (Felder, 2006).

Felder (1997) had the following to say regarding the implementation of inquiry related teaching methods in technical classrooms:

> Moving to a student-centered instructional approach may not be an easy step for professors of technical subjects (or any other subjects, for that matter). They have to deal with the fact that while they are learning to implement the new approach they will make mistakes and may for a time be less effective than they were using more familiar teacher-centered methods. They may also have to confront and overcome substantial student opposition and resistance, which can be a most unpleasant experience, especially for teachers who are good lecturers and may have been popular with students for many years. The experience of the longitudinal study suggests that instructors who pay attention to collaborative learning principles when designing their courses, who are prepared for initially negative student reactions, and who have the patience and the confidence to wait out these reactions, will reap their rewards in more positive student attitudes toward their subjects and toward themselves, and probably in more and deeper student learning (although it may be difficult to quantify the latter outcomes). It will take an effort to get there, but it is an effort well worth making (Felder, 1997, p. 5).

As more studies are conducted to demonstrate the advantages of using inquiry methods in technical classrooms it will begin to gain its own inertia. The literature related to inquiry teaching is very encouraging. This research seeks to reveal patterns and themes evident in technical classrooms using inquiry-based learning methods.

2.5. The Effect of Discussion on Learning

As mentioned in a preceding section, Vygotsky believed that higher learning can be best facilitated through a social interaction between teacher and student. Accordingly, the National Science Education Standards state that student understanding of science curriculum should be "actively constructed through individual and social processes" (National Research Council, 1996, p.28). One such social process that can have a positive impact on learning is discussion, or talking in the classroom.

VonGlaserfeld (1993) stresses the importance that classrooms be structured in a manner that allows for discussion between teacher and pupil. He points out that "language is learned in the course of interaction with other speakers, because speaking is a form of interacting, and we modify our use of words and utterances when they do not yield the expected results" (p.30). As ideas, interpretations, and information ebb and flow between teacher and student, lessons can be dynamically adapted to address areas of misunderstanding. VonGlaserfeld (1993) also points out another advantage gained in classrooms that encourage discussion. He states, "insofar as a classroom is interactive, it contributes to the students' linguistic development and also provides them with opportunities to witness the use of words in the context of the experiences to which they refer" (p.30). As students contribute in classroom discussions, they must draw upon their knowledge banks to make inferences or assumptions about the subject at hand. This process of verbalizing helps commit the new information to memory, and allows the student to properly align it within existing knowledge structures. Also, according to Biggs (1999), students who talk about what they are learning will retain a greater portion of the material.

Rivard and Straw (2000) conducted a study which suggests that talk in the classroom has a significant positive effect on learning. The study was comprised of 43 students who were separated into 4 groups: control, talk only, write only, and talk and write. The groups were all given a pretest to determine a baseline from which to measure. After the experimental period, the students were administered a posttest. What they found was very interesting. The results showed that talk had a significant impact on the achievement and depth of understanding. The study showed that "talk is important for sharing, clarifying, and distributing scientific ideas" (p.588). The students who participated in the control and write-only groups performed significantly lower than the groups whose instruction included class and peer discussion.

The role of talk in learning has been studied by several scholars (Rivard, 2000). One such scholar, Britton (1982), suggests the following:

> We come to an understanding in the course of communicating it. That is to say we set out by offering an understanding and that understanding takes shape as we work on it to share it. And finally we may arrive co-operatively at a joint understanding as we talk or in some other way interact with someone else (p.115).

Talk is extremely important to learning. This excerpt from Britton highlights the oft experienced phenomenon of synergy where the whole is greater than the sum of its parts. Effective learning environments foster synergistic open dialogue where teachers and students work cooperatively to learn. When structured properly, talk is a very effective teaching tool. Students are far more likely to remember a conversation they helped to form than they will a lecture where they passively participated.

2.6. Summary

Most learning theories attempt to understand and explain the learning process from a developmental and psychological level. Piaget and Vygotsky both suggest that deep learning does not occur until the learner is sufficiently mature and is capable of formal operational thought. However, Vygotsky's theory of proximal development suggests teachers can help accelerate and improve learning through coaching and interaction. Constructivist theory stresses the importance of interaction between teacher and learner. It also suggests that knowledge is built or constructed on an individual level and that interaction with others is paramount in the creation of knowledge.

This idea of improved learning through increased interaction is integral to this study. This study has been built upon the premise that by increasing the interaction between student and teacher, learning will be improved. In order to promote increased interaction, this study has sought to foster a classroom atmosphere to encourage inquiry learning. The inquiry approach was selected as a means to increase learning because it seeks to promote free and open discussion, supports the use student ideas, and cultivates questioning – all of which encourage interaction (Zevin, 1973).

Bloom's research in mastery learning has important implications for this study. He proposed that if instruction is personalized to the individual that a large percentage of students will reach a mastery level of achievement. By integrating inquiry methods in the classroom, interaction should increase which will allow teachers to more effectively tailor their instruction to the individual needs of each student. If each student can learn according to the cues to which they respond best, then learning should be enhanced.

Several studies involving inquiry learning have been conducted in science classrooms. The results of these studies have consistently shown that students participating in inquiry instruction tend to have better attitudes about their learning experience. The results concerning performance on test instruments have been mixed. Some studies have suggested an improvement in achievement while others have found no significant difference between inquiry groups and traditionally taught groups. Perhaps an explanation for this is that test instruments do not completely evaluate all facets of learning. This research undertaking seeks to explore further the effect of implementing elements of inquiry learning in technical undergraduate classrooms. As the experiment is conducted and data analyzed, outcomes will be evaluated for recurring themes and patterns found in the existing research.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

The goal of this exploratory study was to determine what kind of impact an inquiry-based teaching approach would on student achievement in technical undergraduate courses. The study was designed in such a manner as to compare the learning results from an inquiry-based group and a group taught with a traditional lecture. For purposes of the study, student achievement was measured along two lines. The first aspect of achievement was student performance on pre- and post-test instruments. The second aspect of achievement was that of attitude as measured by a survey.

As discussed in Chapter 2, inquiry-based learning can be much more effective than traditional lectures. Classrooms fostering inquiry are often much more interactive than traditional classrooms. In an effort to create a classroom espousing elements of inquiry-learning, the researcher designed an instructional scheme that replaced a standard 50 minute, two-day-a-week lecture, with a 50-minute, once-a-week, question and answer session, based upon pre-assigned readings.

This instructional scheme was conceived as a result of the researcher participating previously in a special topics course with a professor within the School of Technology. This particular course was taught on a one-on-one basis. The researcher was asked to come once a week with questions relating to pre-assigned readings. What occurred in the course of instruction was an increase in the student's responsibility for his learning. Also, he was able to get clarification for areas of confusion as well as, gain insight on the material he found most interesting. The result was a very rich learning experience for both the professor and researcher. After participating in this arrangement, the researcher felt that such an approach in undergraduate instruction in technical courses could be very beneficial. The undertaking of this research stems from that experience.

3.2. Experimental Design

In order to evaluate the effect of an inquiry-based learning approach, the researcher selected three courses for experimentation taught through the School of Technology at Brigham Young University: Quality Systems , Polymer Processing , and Manufacturing Automation. The courses used for this study all dealt with a technical subject matter. Each class was divided into two groups – an experimental group and a control group. The experimental group was asked to not attend the regularly scheduled class, but instead to attend an alternate session where instruction would follow a question and answer format. Because the experimental groups would meet at times other than the normal class time, it was necessary to solicit volunteers for the study. In this regard, the experimental groups are not random, but a self-selected sample. The researcher felt however, that regardless of the self-selection bias, the results would be of value and interest.

Table 3-1 has been included to show the similarity of the experimental group to the control group. The table shows similarities along four dimensions: average age, gender, class standing, and major. The groups are very similar, and the self-selection bias will not be considered an important factor.

Table 3-1: Similarity of Experimental and Control Groups

	Treatment	Average Age	Gender		Class Standing			Major	
			Male	Female	Soph.	Junior	Senior	MET	Other
Quality Systems	Experimental	24.4	18	1	0	0	19	18	1
	Control	24.1	15	2	0	1	16	16	1
Polymer Processing	Experimental	24.9	12	2	0	5	9	11	3
	Control	24.1	39	5	2	9	33	33	11
Manufacturing Automation	Experimental	25.2	13	0	0	0	13	n/a	n/a
	Control	25.3	23	2	0	2	23	n/a	n/a

3.2.1. Participating Courses

The researcher wished to collect data during the Fall 2006 and Winter 2007 semesters. Participant courses were limited to those taught in the School of Technology whose subject matter was technical in nature. Originally, the researcher intended to conduct the study in just two courses, but was able to find three professors who were willing to have their classes participate in the study. Each class and particulars of the experiment will be discussed below.

3.2.1.1. Quality Systems

During the Fall semester of 2006, data were collected on the students participating in the Quality Systems course. Quality Systems is a course that focuses on principles of quality in manufacturing processes. The topic being covered during the portion of the Quality Systems Class during which this study was conducted was design of experiments (DOE). DOE is a tool used by engineers to determine which factors have the greatest impact on a measured outcome. It is a topic to which most of the students enrolled in the course have had very limited exposure.

From the start of the semester in September through the end of October, the course was taught as normally done with no separation into a special study group. From November 2, 2006 until December 1, 2006, the class was split into experimental and control groups. The course consisted of a total of 36 students, 17 participated in the control group and 19 participated in two experimental groups; one consisting of 10 students and the other 9. One group met Thursday at 11 AM and the other on Friday at 1 PM. The students in the experimental groups were given study questions to serve as a guide as they read from an assigned text. There was no difference in the instructional format between the two experimental groups. The only difference was the questions the students asked.

3.2.1.2. Polymer Processing

Data for the Polymer Processing course were gathered between January 15, 2007 and February 9, 2007. This course is intended to build an understanding of plastics materials, their properties, uses, and processing techniques. The topics covered during the experimental period coincided with the first five chapters of the course textbook — introduction to plastics, polymeric material, microstructures in polymers, mechanical properties, and chemical and physical properties. This class consisted of 70 students. Fourteen participated in the experimental group and the remainder served as the control. Students in the experimental group were instructed to read according to the schedule on the course syllabus and to use the questions at the end of each chapter to help steer their efforts. The group then attended class every Friday at 1 PM and asked the instructor questions about the material they had read.

3.2.1.3. Manufacturing Automation

The experiment for Manufacturing Automation was carried out between the dates of January 9, 2007 and February 2, 2007. This course had an enrollment of 47 students, 13 of whom participated in the experimental group. Scheduling an alternate time for the experimental group to meet proved to be especially difficult for this class. Because of varying student schedules three separate times were assigned for the experimental instruction. The times set aside were Tuesday at 5 PM, Friday at 7 AM, and Friday at 2 PM. Originally, students were assigned specific times to attend, but after the first week were allowed to attend anytime during the week they chose.

As well as having less structure regarding meeting times, the experimental group in this class also had much less structure in reading assignments. They were instructed to attend the question and answer session with questions relating to the topics outlined in the course syllabus. However, the textbook for the course did not cover all of the topics covered in the class. Significant portions of course material are delivered during class lectures. When material was not covered in the textbook, students were instructed to seek out information on their own, either online or by means of the school library.

3.2.2. Data Collection Methods & Validity

The primary data collection instruments used in the study included measures of knowledge and attitude. Knowledge was measured through pre- and post-test instruments. These assessment instruments covered the material that would be taught during the experimental instruction in each course. They were primarily adaptations of problems and concepts found in course texts. Attitudinal data was collected by means of a pre- and post-survey. These surveys were constructed with questions regarding attitude, learning preferences, and general feelings about the instruction received. The tests represent quantitative data while the surveys are much more qualitative in nature. Chang and Mao (1999) used a similar approach when conducting their study; they too utilized both qualitative and quantitative data. They administered both a pre- and a post-test, identical in form, at the beginning and end of their experiment. They also administered an "attitudes inventory," to measure students' feelings towards the instructional approaches. In this manner, they were able to measure how much each group improved during the experimental instruction as well as how their attitudes changed. Rivard and Straw (2000) also used a similar technique in their investigation of the effect of talk on learning. They used a pre- and post-test. However, the post-test was slightly different than the pre-test – it covered the same material, at the same difficulty level, but used different questions.

Secondary sources of data utilized by the researcher included scores from course exams, instructor surveys, and researcher observations. The researcher intentionally employed several data collection methods to allow for the substantiation of trends through multiple data sources. As research results are interpreted the researcher will use data collected from the pre- and post-tests, and pre- and post- surveys in conjunction with secondary sources of data (course exams, instructor surveys, and observations). "By combining multiple observers, theories, methods, and empirical materials, researchers can hope to overcome the weakness or intrinsic biases and the problems that come from single method, single-observer, single-theory studies" (State University of New York, 2006).

In order to allow for a sound and robust evaluation of trends and patterns and to establish validity, more than one source of data should be used. This practice is often referred to as triangulation. According to Guion (2002), there are five main types of triangulation: data triangulation, investigator triangulation, theory triangulation, methodological triangulation, and environmental triangulation. For this study, methodological triangulation was deemed most appropriate. "Methodological triangulation involves the use of multiple qualitative and/or quantitative methods to study [a problem]" (Guion, 2002, p. 2). When conclusions from each of the methods used are the same, then validity has been established (Guion, 2002). To evaluate whether there is an interaction effect between student learning and method of instruction, the pre- and post- tests for each course will be evaluated in conjunction with the corresponding results from the regular course exam. Current literature will consulted to bring clarity and perspective to the findings. To evaluate whether an interaction effect exists between student attitudes and method of instruction, the pre- and post- surveys will be used in conjunction with researcher observations and instructor surveys. Again, current literature will be consulted to help understand the results.

3.3. Summary

Inquiry learning can be much more effective than traditional lecture learning. To discover the effect of integrating inquiry learning in technical classrooms, the researcher designed a classroom environment which espoused and encouraged behaviors consistent with inquiry learning. The researcher then followed a methodological approach to collect data varying in type and source. By utilizing a diverse set of data the researcher was better able to interpret and understand the results of the study. This approach was consistent with techniques of methodological triangulation.

To further establish validity, the study was conducted in three different classrooms with three different instructors, and with three different subjects. This approach has helped assess the effects of inquiry learning in technical classrooms. This also translates into much broader applicability for technical undergraduate course design.

CHAPTER 4: RESULTS AND FINDINGS

4.1. Introduction

This chapter presents results from each of the three classes that participated in the study. This study sought to answer two research questions: 1) is there a difference in student learning related to the use of traditional lecture or inquiry-based instructional methods in technical classes, and 2) is there a difference in student attitude towards course material related to the use of traditional lecture or inquiry-based instructional methods in technical classes. The researcher employed several methods for data collection in order to understand the effect, if any, of the inquiry-based instruction on the students. To measure learning and knowledge growth, pre- and post-tests were used, as well as, the scores from a regular course examination. To measure student attitudes, the researcher administered pre- and post-surveys. For each class, the post survey contained a set of questions answered by the control and experimental groups, as well as, a set answered only by the experimental group. Additionally, the researcher surveyed the instructors who participated in the study, and observed the instruction in the experimental classes. The results from each of these methods has been organized and is presented in following order: 1) the results from the pre- and post- tests for each class, 2) results from the regular class exams, 3) results from the pre- and post- surveys, 4) results from the experimental-only survey, 5) results from the instructor surveys, and 6) researcher observations made during the study.

The experiment in each class was conducted in as similar a manner as possible. For example, at the onset of the experiment each professor was instructed that class discussion during the experimental sessions should revolve around student questions. One area where it was very difficult to achieve conformity across courses was in the number and size of the experimental groups. The experiment in the Polymer Processing course was conducted with one experimental group of 14 (n=14). The experiment in the Quality Systems course was conducted with two experimental groups: one group of nine (n=9), and the other ten (n=10). The experiment in the Manufacturing Automation course was conducted with three experimental groups: two groups of four (n=4) and one group of five (n=5). (see Table 4-1 below for details)

Table 4-1: Participating Courses Number of Groups and Size

	Experimental Groups	Experimental Group Sizes	Total Participants		
			Experimental	Control	Combined
Polymer Processing	1	14	14	44	58
Quality Systems	2	9,10	19	17	36
Manufacturing Automation	3	4,4,5	13	25	38

Note: the Polymer Processing course had a total enrollment of 70, however, 12 students from the control group failed to take both the pre- and post-tests and were excluded from the analysis. The Manufacturing Automation course had a total enrollment of 47, with 9 students in the control group excluded from the analysis for failure to complete the pre- and post-tests.

Due to the small sample sizes the researcher felt it was reasonable and necessary to consolidate the Manufacturing Automation experimental groups into one group for purposes of statistical analysis. Analysis regarding the Quality Systems course was done handling the experimental groups individually as well as combined. Because the sample sizes are relatively small, it is also appropriate to use a confidence level of 90% when conducting tests for significance. Setting this confidence level allows greater latitude in identifying potentially important differences between the outcomes for the experimental and control groups.

4.2. Results from Pre- and Post-tests

The process used to evaluate the results from the pre- and post-tests in each course followed the same general approach. In each course, a test for significance was conducted using a computed gain score (post-test score less pre-test score). The analysis used to test for significance was a two sample t-test. The purpose of the t-test is to determine if two population means are equal. This is done by comparing the difference between two means, divided by an estimated standard deviation to assess significance (Snedecor, 1989). The important outputs from a t-test are the t-statistic (t-stat), and its associated probability (p-value). The t-stat is a measure of distance between sample means, the p-value indicates the probability, due to chance, of obtaining the observed t-stat. When the probability is sufficiently low, in our case less than 0.10, it can be concluded that the means for the groups are not the same.

When conducting t-tests, there are two kinds of tests to choose from – one which assumes equal variance between samples, and one which assumes unequal variance. To determine which test to use, a test for equal variance was completed for each data set. Based upon accepted convention, unequal variance was assumed when the test for equal variance yielded a p-value of less than 0.05 (Snedecor, 1989).

4.2.1. Quality Systems

The data for the Quality Systems course was evaluated using a two sample t-test assuming equal variances. The results of the test revealed no significant difference between the means for the two groups. The reported p-value was 0.37. An analysis of variance (ANOVA) was also conducted for this course. An ANOVA was used in addition to the t-test because in this class there were two experimental groups of moderate size. ANOVA works by weighing the variation between multiple groups (a control and two or more experimental groups) and the independent variable which in our case is the method of instruction. The results of the ANOVA, consistent with those from the t-test, showed no significant difference between the groups at a 90% level. The observed p-value was 0.52. Thus, the ANOVA which handled the groups individually, as well as the t-test which combined the experimental groups, suggested no effects of method of instruction on gain scores.

Although there was no significant difference between the two groups, it should be noted that the experimental group received half as much in-class instruction as did the control group. The control group met eight times while the experimental group met only four times. For reasons of confounding, we cannot simply weight the gain scores and run another test for significance, but based upon the scores from the pre-and post-tests, the experimental group performed on par with the control group. The table below shows the observed pre- and post-test means.

Table 4-2: Observed Means Scores and Gain Score Standard Deviation

	Pretest Mean	Posttest Mean	Gain Mean	Gain Std Dev
Experimental	37.99%	69.47%	31.48%	15.06%
Control	33.33%	69.33%	36.00%	15.06%

4.2.2. Polymer Processing

The results from the pre- and post-tests for the Polymer Processing course were evaluated and a gain score for each participant was computed. The gain scores were evaluated using a two sample t-test to identify a significant difference between the experimental and control groups. The t-test output revealed a t-stat of 1.71, and a p-value of 0.092. These results (see Table 4-6) suggest that the chance of observing the t-stat we observed is 9.2%. Thus at a 90% level we are confident that there is an effect of method of instruction and student learning—the gain score means for the groups are not the same.

Table 4-3: T-Test Results for Polymer Processing Class Gain Score

	Experimental	*Control*
Mean	0.3929	0.3125
Variance	0.0176	0.0251
Observations	14	44
Pooled Variance	0.0234	
Hypothesized Mean Difference	0	
df	56	
t Stat	1.7123	
P(T<=t) one-tail	0.0462	
t Critical one-tail	1.6725	
P(T<=t) two-tail	0.0924	
t Critical two-tail	2.0032	

As with the Quality Systems course, it should be noted again that the students in the experimental group met only once a week as opposed to two times a week for the control group. When considered in that context, the significance of these results is that much more poignant.

4.2.3. Manufacturing Automation

The Manufacturing Automation pre- and post-tests differed from the tests in the other courses in that the pre- and post-tests were not identical. Both tests covered the same material, at the same difficulty level, but the questions were different. Each test was graded and a gain score was computed by subtracting the pretest score from the posttest score. The computed gain scores were then analyzed using a two sample t-test to determine if there existed a significant difference between the means for the control and experimental groups. Two students in the experimental group failed to take the posttest, and as a result the sample size (N) for the t-test was 11 as opposed to the 13. The test showed a p-value of 0.41 suggesting no difference between the two groups. When the test was conducted using all 13 participants and assigning a gain score of zero to the two missing students, the p-value was 0.74.

Although the t-test for gain scores showed no significant difference, the experimental group received half as much instruction as did the control group. Based on this difference the relative performance is very interesting.

4.2.4. Summary

The results from the analysis of the pre- and post-test gain scores produced mixed results. In the Quality Systems and Manufacturing Automation courses, tests for significance revealed no difference in the gain scores between the control and the experimental groups. However, the results in the Polymer Processing course showed a significant difference at a 90% level between the groups. In all cases, the experimental group met half as often as the control group and performed at a level at least comparable to the control group.

4.3. Results from Regular Class Exam

To gain more insight into student achievement, a regularly scheduled exam was also selected as a data source. In each class, the exam scores for the two groups were compared using a t-test to determine whether there existed a significant difference. As stated before, significance was determined at p-valued less than 0.10.

4.3.1. Quality Systems

In the Quality Systems course, the exam used for this information was taken by the students two weeks after the conclusion of the experimental instruction. The scores for the experimental group as well as those for the control group were evaluated using a two sample t-test. When conducting this test, two students in the control group were excluded due to extraordinarily poor scores on the test (outliers). A two sample t-test assuming unequal variances (the test for variance resulted in a p-value less than 0.05) was conducted The results of this test revealed a p-value of 0.094, see Table 4-3. These results suggest the chance of observing a t-stat at this level is 9.4%. With 90% confidence we can reject the null hypothesis that there is no effect of method of instruction on student learning.

Table 4-4: T-Test Results for Regular Exam

	Experimental	*Control*
Mean	24.526	25.600
Variance	5.152	1.686
Observations	19	15
Hypothesized Mean Difference	0	
df	29	
t Stat	-1.734	
P(T<=t) one-tail	0.047	
t Critical one-tail	1.311	
P(T<=t) two-tail	0.094	
t Critical two-tail	1.699	

4.3.2. Polymer Processing

In the Polymer Processing course, scores from a midterm exam completed during the final week of the experiment were evaluated as a second source of data. The scores from this exam were analyzed using a two-sample t-test to determine if the difference in means between the groups was significant. The results yielded a t-stat of 0.55, and a p-value of 0.59. These results suggest no significant difference between the means of the two groups.

4.3.3. Manufacturing Automation

In the Manufacturing Automation course, scores from a midterm taken one week following the conclusion of the experiment were evaluated as a second source of data. The scores from this exam were analyzed using a two sample t-test to determine if the difference in the means between the groups was significant. The results yielded a t-stat of -0.98, and a p-value of 0.34. These results suggest no significant difference between the means of the two groups.

4.3.4. Summary

As with the results from the gain scores, the results from the analysis of scores on a regular course exam were mixed. The results from the Polymer Processing, and Manufacturing Automation courses showed no significant difference between the control and experimental groups. However, the results from the Quality Systems course showed a significant difference at a 90% confidence level.

4.4. Results from Pre- and Post-Surveys

To measure changes in attitude students were given surveys at the beginning and end of the treatment. The pre-survey included questions relating to attitudes that were paired with corresponding questions on the post-survey. In the Quality Systems course, there were three paired questions. The Polymer Processing course as well as the Manufacturing Automation course had one paired question and 12 additional attitudinally oriented questions on the post-survey.

The answer choices for the paired questions conformed to a six option Likert scale (see Table 4-5 for an example). If a student reported "b" on the pre-survey, and "a" on the post-survey, they were allotted an improvement score of 1. If they moved from a "c" to an "a," they were allotted a 2, and so on and so forth. The scores derived from this process were then analyzed using a two sample t-test.

The 12 additional questions asked on the post-survey in the Polymer Processing and the Manufacturing Automation courses were also designed with Likert scale responses. These responses, like the paired questions, were assigned a numeric value for purposes of analysis. The control group and experimental group were then compared using a two sample t-test to identify any significant difference. This was performed for each question.

4.4.1. Quality Systems

As mentioned, the pre- and post-surveys in the Quality Systems course contained three paired questions relating to student attitude. From the pre-survey questions 5, 6, and 7, were paired with questions 6, 3, 4, respectively from the post-survey. (see Appendices for surveys) By pairing the questions in such a manner, the researcher was able to measure how the students' attitudes changed during the experiment.

The three paired questions all dealt with students' confidence in their ability to apply course related material to real world applications. For this reason, the responses from the questions were combined to form a composite score. The questions used to form the composite score with their associated pre- and post-survey frequency distributions are recorded in Table 4-5.

Table 4-5: Questions Comprising the Attitude Composite Score & Response Frequency

Questions Pre 5 / Post 6	I would describe my understanding of statistical principles as:			
	Exp (Pretest)	Contr (Pretest)	Exp (Posttest)	Contr (Posttest)
a)very good	0%	0%	5%	7%
b)good	53%	47%	89%	73%
c)neither good or bad	47%	47%	5%	13%
d)poor	0%	6%	0%	7%
e)extremely poor	0%	0%	0%	0%
Questions Pre 6 / Post 3	How would you describe your confidence in using statistical concepts to understand and improve a manufacturing processes?			
	Exp (Pretest)	Contr (Pretest)	Exp (Posttest)	Contr (Posttest)
a)very confident	0%	6%	5%	20%
b)confident	35%	53%	79%	53%
c)neutral	53%	35%	16%	20%
d)unconfident	12%	6%	0%	7%
e)very unconfident	0%	0%	0%	0%
Questions Pre 7 / Post 4	Based on your experience in methods and/or statistics courses, how would you describe you ability to correctly apply information learned to real world situations?			
	Exp (Pretest)	Contr (Pretest)	Exp (Posttest)	Contr (Posttest)
a)always able	0%	0%	5%	13%
b)often able	24%	41%	79%	60%
c)sometimes able	65%	53%	16%	27%
d)rarely able	12%	6%	0%	0%
e)never able	0%	0%	0%	0%

A visual inspection of the frequency of the responses for these questions suggests improvements in the attitudes of the experimental group. To determine if the difference in responses were in fact significant, the researcher conducted a two sample t-test. The results of the t-test, see Table 4-6 below, yielded a p-value of 0.04. This means we are confident at a 95% level that the means for the composite attitude scores for the two groups are not the same. We can reject the null hypothesis.

Table 4-6: T-Test Results for Attitude Composite Scores

	Experimental	*Control*
Mean	1.9412	1.0667
Variance	1.8088	0.7810
Observations	17	15
Pooled Variance	1.3292	
Hypothesized Mean Difference	0	
df	30	
t Stat	2.1413	
P(T<=t) one-tail	0.0202	
t Critical one-tail	1.3104	
P(T<=t) two-tail	0.0405	
t Critical two-tail	1.6973	

4.4.2. Polymer Processing

To assess a change in attitude during the test period, two questions (one on each survey) were paired together on the pre- and post-surveys. The questions, (see Table 4-7), dealt specifically with students' attitude about their confidence in using Polymer Processing knowledge to improve a manufacturing process. Similar to the analysis done for the Quality Systems course, an improvement score was calculated for each participant. The answer choices for the questions followed a six-option Likert scale from "very confident" to "very unconfident." The results from a two sample t-test, assuming unequal variances, showed no significant difference between the control and experimental groups. The reported p-value was 0.28.

Table 4-7: Paired Attitude Question on Pre- and Post-Surveys and Response Frequency

Question Pre	Question Post	How would you describe your confidence in using your knowledge of plastics to improve a manufacturing process?			
6	4				
		Pretest Exp	Pretest Control	Posttest Exp	Posttest Control
a) Very confident		0.00%	0.00%	7.14%	4.55%
b) Confident		7.14%	2.27%	64.29%	50.00%
c) Neutral		21.43%	31.82%	28.57%	38.64%
d) Poor		57.14%	59.09%	0.00%	6.82%
e) Extremely poor		14.29%	6.82%	0.00%	0.00%

In addition to the paired question, the post-survey for this course included 12 attitudinal directed questions. These questions were individually evaluated for significance. At the 90% level or higher, the responses for three questions were found to be significant. These questions are as follows:

Question 10: Do you feel that all of your questions regarding course content have been answered during class?

a) Strongly agree
b) Agree
c) Not sure
d) Disagree
e) Strongly disagree

Question 13: In an average class period I have asked:

a) 0-1 questions
b) 1-3 questions
c) 3+ questions

Question 14: Did you always attend lecture?

a) Never missed
b) Missed 1 time
c) Missed 2 times
d) Missed 3 or more times

Each of these questions returned p-values of less than 0.10. Specifically, p-values of 0.054, 0.000, and 0.090 were recorded for questions 10, 13, and 14, respectively. The questions revolved around the subject of student questioning and attendance. Students in the experimental group reported a higher incidence of question asking, and a larger number of their questions answered during class. They also reported better attendance than the control group.

Two other questions that did not show significance but merit mention were questions eight and four. Question eight asked "did lectures extend your knowledge beyond the textbook?" The frequency distribution, shown in Table 4-8, for the responses to this question showed that 100% of the experimental group answered in the affirmative while 86% of the control group did.

Table 4-8: Polymer Processing Post-Survey Question 8

8) Did lectures extend your knowledge beyond the textbook?				
	Experimental	Control	Experimental	Control
a Strongly Agree	4	11	28.57%	25.00%
b Agree	10	27	71.43%	61.36%
c Not Sure	0	5	0.00%	11.36%
d Disagree	0	0	0.00%	0.00%
e Strongly Disagree	0	1	0.00%	2.27%
	14	44	100.00%	100.00%

Question four was also interesting. This question asked "How would you describe you confidence in using concepts learned in this class to improve a plastics manufacturing process?" The response frequencies, shown in Table 4-9, show that 71% of the experimental students, as opposed to 55% of the control students responded in the affirmative.

Table 4-9: Polymer Processing Post-Survey Question 4

4) How would you describe your confidence in using concepts learned in this class to improve a plastics manufacturing process?				
	Experimental	Control	Experimental	Control
a Very Confident	1	2	7.14%	4.55%
b Confident	9	22	64.29%	50.00%
c Neutral	4	17	28.57%	38.64%
d Unconfident	0	3	0.00%	6.82%
e Very Unconfident	0	0	0.00%	0.00%
	14	44	100.00%	100.00%

4.4.3. Manufacturing Automation

Results from the paired question for the Manufacturing Automation class showed no significant difference between the control and the experimental group. The results from the 12 additional attitude-based questions revealed that the response to just one question, number 8, was significantly different between the groups. Question 8 asks, "How do you feel about coming to lectures in this class?" A two sample t-test showed the mean for the experimental group was significantly different from that of the control group. The mean response for the experimental group on a 5 point scale, 5 being very positive, was 3.81 as opposed to 3.32 for the control group. The t-stat of 1.94 and p-value of 0.06 suggests that the chance of observing the observed difference between the means for these groups is 6%.

In a similar fashion to the Polymer Processing course, the researcher evaluated frequency distributions for each of the questions on the post-survey to identify any interesting patterns. No other questions on this portion of the post-survey demonstrated significance or merited further investigation.

4.4.4. Summary

Data relating to student attitudes were gathered through the use of pre- and post-surveys. Through the pairing of questions on the pre- and post-surveys, the researcher hoped to record how students' attitudes changed during the experimental period. The researcher also included 12 additional attitude questions on the Polymer Processing and Manufacturing Automation post-surveys to understand how students in those courses felt about the instruction they had received. According to the paired questions in the Quality Systems class, students in the experimental group reported better attitudes in the area of confidence than the students in the control group. In the Polymer Processing and Manufacturing Automation classes, where additional questions relating to attitude were asked, significant differences were found. In the Polymer Processing course, students in the experimental group reported to have had more of their questions answered during class, to have asked more questions, and to have had better attendance. In the Manufacturing Automation class, students in the experimental group reported to have been more excited to come to class than their peers in the control group.

The data suggests that the null hypothesis, that the attitudes among the control and experimental groups are the same, can be rejected for the Quality Systems and Polymer Processing classes. However, only one question on the post-survey showed a significant difference between the groups for the Manufacturing Automation course. This single question is not sufficient evidence to reject the null hypothesis in the case of the Manufacturing Automation course.

4.5. Results from Experimental-Only Survey Questions

The post-survey consisted of two sections – one section that both the control and experimental groups completed, and another section that only the experimental group completed. The intent of the experimental-only section was to learn how the students in the experimental groups responded to and felt about the experimental instruction. This section was comprised of several survey questions and also provided the students a space to share comments, feelings, and thoughts about their experience. Although this data is not intended for statistical analysis of differences, it is very informative. It is often easy for researchers get caught up in the details of analysis and forget to look at the broad picture and general outcomes. These data should help readers understand how the participants felt about the experimental instruction which influenced their attitudes, i.e., the ways in which attitudes are affected. In the following sections, the student responses for this portion of the survey will be reported.

4.5.1. Common Questions

The experimental-only survey consisted of 11 questions in the Quality Systems course, 13 in Polymer Processing, and 10 in Manufacturing Automation. Common among all courses were nine questions. These nine questions will be presented below with response frequencies sorted by course.

1) I liked the question/answer class format. (Circle one):

Table 4-10: Answers Post-survey Common Question 1

	Quality		Plastics		Automation		Total	
	Students	%	Students	%	Students	%	Students	%
a Strongly Agree	8	44%	11	79%	6	55%	25	58%
b Agree	6	33%	2	14%	2	18%	10	23%
c Not Sure	1	6%	0	0%	1	9%	2	5%
d Disagree	3	17%	1	7%	2	18%	6	14%
e Strongly Disagree	0	0%	0	0%	0	0%	0	0%

2) I feel I would have learned more about [this course] if I had <u>not</u> participated in the experimental group. (Circle one):

Table 4-11: Answers Post-survey Common Question 2

	Quality		Plastics		Automation		Total	
	Students	%	Students	%	Students	%	Students	%
a Strongly Agree	1	6%	0	0%	3	27%	4	10%
b Agree	2	12%	0	0%	2	18%	4	10%
c Not Sure	4	24%	5	36%	2	18%	11	26%
d Disagree	8	47%	5	36%	2	18%	15	36%
e Strongly Disagree	2	12%	4	29%	2	18%	8	19%

3) I liked having the opportunity to ask questions about material I did not understand and to receive immediate feedback. (Circle one):

Table 4-12: Answers Post-survey Common Question 3

	Quality		Plastics		Automation		Total	
	Students	%	Students	%	Students	%	Students	%
a Strongly Agree	9	50%	9	64%	7	64%	25	58%
b Agree	8	44%	5	36%	4	36%	17	40%
c Not Sure	0	0%	0	0%	0	0%	0	0%
d Disagree	1	6%	0	0%	0	0%	1	2%
e Strongly Disagree	0	0%	0	0%	0	0%	0	0%

4) I find that participating in the study (Circle one):

Table 4-13: Answers Post-survey Common Question 4

		Quality		Plastics		Automation		Total	
		Students	%	Students	%	Students	%	Students	%
a	Helped my learning	12	63%	12	86%	6	55%	30	68%
b	Adversely affected my learning	1	5%	1	7%	3	27%	5	11%
c	was not much different than a normal class	6	32%	1	7%	2	18%	9	20%

5) The experimental group would have been more helpful if (Circle one):

Table 4-14: Answers Post-survey Common Question 5

		Quality		Plastics		Automation		Total	
		Stud	%	Stud	%	Stud	%	Stud	%
a	you were assigned to an outside discussior group where you discussed readings and course material with your peers	6	35%	4	29%	1	9%	11	26%
b	You were required to report on the amount of preparation you performed outside of class	4	24%	2	14%	2	18%	8	19%
c	you were given specific study questions	3	18%	8	57%	6	55%	17	40%
d	the readings were coupled with homework problems	4	24%	0	0%	2	18%	6	14%

6) As compared to other learning experiences regarding a technical subject do you feel that during the experimental format (Circle one):

Table 4-15: Answers Post-survey Common Question 6

		Quality		Plastics		Automation		Total	
		Students	%	Students	%	Students	%	Students	%
a	you were better appraised of your progress and understanding of material	9	50%	7	50%	5	45%	21	49%
b	you were less appraised of your progress and understanding of material	5	28%	4	29%	2	18%	11	26%
c	no different from what I am used to	4	22%	3	21%	4	36%	11	26%

7) T / F Given the opportunity, I would participate again in similar question-oriented classes.

Table 4-16: Answers Post-survey Common Question 7

	Quality		Plastics		Automation		Total	
	Students	%	Students	%	Students	%	Students	%
a True	16	84%	13	93%	7	64%	36	82%
b False	3	16%	1	7%	4	36%	8	18%

8) T / F I feel that I had more interaction with the teacher than I would have had in a normal lecture.

Table 4-17: Answers Post-survey Common Question 8

	Quality		Plastics		Automation		Total	
	Students	%	Students	%	Students	%	Students	%
a True	17	89%	13	93%	8	73%	38	86%
b False	2	11%	1	7%	3	27%	6	14%

9) Y / N If you felt you had more interaction, do you feel that it was beneficial to your learning?

Table 4-18: Answers Post-survey Common Question 9

	Quality		Plastics		Automation		Total	
	Students	%	Students	%	Students	%	Students	%
a Yes	17	100%	13	100%	8	100%	38	100%
b No	0	0%	0	0%	0	0%	0	0%

4.5.2. Quality Systems

In addition to the nine common questions, the Quality Systems course had two other questions on the experimental-only post-survey. These questions, with response frequencies, are shown below:

8) As compared to regular class instruction, I was _______ about class during the experimental instruction. (Circle one):

		Students	%
a.	Much more excited	4	22%
b.	More excited	7	39%
c.	Same excitement	5	28%
d.	Less excited	2	11%
e.	Much less excited	0	0%

11) Regarding the "Test Group Study Questions," I (Circle one):

		Students	%
a.	went through every question thoroughly	2	11%
b.	went through most of the questions thoroughly	6	33%
c.	went through some of the questions thoroughly	9	50%
d.	did not use them	1	6%

4.5.2.1. Student Comments, Feelings, and Thoughts

At the end of the post-survey, the students were also given the opportunity to share comments, feelings or thoughts about their experience. Here is what the students in the Quality Systems course had to say:

- “This works well if you keep motivation up, and through your own efforts, more is learned. Sadly, often it is easier to be forced to learn by class.”
- “It forced me to come to class prepared.”
- “One of the reasons I felt I did better was because I had more flexibility in when I studied since there was not as much class.”

- “I enjoyed the experimental class, I just felt like it was a disadvantage to only have one class per week whereas the other students had two.”
- “It is a pretty good format. I just think I didn’t take it quite seriously enough.”
- “I felt compelled to study outside of class, let’s do it again.”
- “I really liked the smaller group and asking questions. Only meeting once a week was a little harder. I felt we would run out of time in meeting only once.”
- “I learned better and enjoyed the smaller classes, but wished I had a second day.”
- “We had more participation which led to increased understanding. I think this method of teaching can be very beneficial to the learning process.”
- “I felt more comfortable asking questions and participating.”
- “I enjoyed being in the experimental group, even though I was very tentative about it at first.”
- “I really liked the format of the class. I didn’t completely understand the reading assignments, so another day during the week meeting as a class would be very beneficial for my learning. I really liked the closer interaction with the professor.”
- “I liked the ability to have questions answered.”
- “I appreciated the experiment, but it didn’t work out well for me. I feel that if we had met more than once and there had been some structure, it would have been better.”

- "I really enjoyed the attention and time that we had with [the professor] during the class time. He answered and went through all the questions we had and helped us understand the principles. I liked the fact that he asked us individually to step to the board and explain the DOE to the rest of the class."
- "The format of the experimental class would be easier and the students could get more out if they were use to the teaching style. For me after the first class period it was easier to understand what was expected."

4.5.3. Polymer Processing

In addition to the nine common questions, the Polymer Processing course had four other questions on the experimental-only post-survey. These questions, with response frequencies, are shown below:

20) Participating in the study required me to take more responsibility for my learning.

		Students	%
a.	Strongly Agree	9	64%
b.	Agree	5	36%
c.	Not Sure	0	0%
d.	Disagree	0	0%
e.	Strongly Disagree	0	0%

23) Did you find this format encouraged you to ask the questions you had?

		Students	%
a.	Strongly Agree	9	64%
b.	Agree	4	29%
c.	Not Sure	1	7%
d.	Disagree	0	0%
e.	Strongly Disagree	0	0%

25) Did you feel that there were times when you did not have questions, and no one else did either?

		Students	%
a.	Always	0	0%
b.	Sometimes	6	43%
c.	Never	8	57%

26) During the study I spent more time outside of class reading and studying course material than I otherwise would have.

	Students	%
True	11	79%
False	3	21%

4.5.3.1. Student Comments, Feelings, and Thoughts

At the end of the post-survey, the students were also given the opportunity to share comments, feelings or thoughts about their experience. Here is what the students in the Polymer Processing course had to say:

- I was more concentrated on the reading and learning the material because it was my responsibility to learn, rather than [the professor's] responsibility to teach me."
- "I really liked it, but one thing that my have strongly influenced that was the small class size in which it was easier to voice questions and comments."
- "I would have liked more guidance – maybe study questions/topics, or 2 meeting times. I love the format, but I feel it is still missing something."
- "I was motivated to read and learn on my own."
- "The question/answer format is nice, but it would be better to have class twice a week or have some type of study group."

- “I felt more attentive, and the need to be prepared in the experimental group.”
- “I would like to have one more meeting time per week for the question and answer session. Either with the professor or T.A.s. I enjoyed the experience. Want to do it again.”
- We didn’t spend a lot of time in class rehashing stuff I already knew.”

4.5.4. Manufacturing Automation

In addition to the nine common questions, the Manufacturing Automation course had one additional question on the experimental-only post-survey. This question, with response frequencies, is shown below:

21) Did you find this format encouraged you to ask the questions you had?

		Students	%
a.	Strongly Agree	6	55%
b.	Agree	2	18%
c.	Not Sure	2	18%
d.	Disagree	1	9%
e.	Strongly Disagree	0	0%

4.5.4.1. Student Comments, Feelings, and Thoughts

At the end of the post-survey, the students were also given the opportunity to share comments, feelings or thoughts about their experience. Here is what the students in the Manufacturing Automation course had to say:

- “I think the experimental class was good, but could have been a lot better just because the experimental groups were too small to carry on a discussion.”

- “It is nice to get immediate feedback but I found it difficult to prepare myself for meetings due to the fact that the time allotted to study quickly and easily disappeared. I need the scheduled lecture to make sure I learn or hear material.”
- “The idea is great however b/c the group met later in the week I did not have time to get my questions answered before the assignments were due.”
- “Too busy with other things so I didn’t do any personal study.”
- “If I had to do it again, I’d stay in the normal class. This really put me behind and I regret doing it. With 18 credits, a family, and a job, I had too much other things going on. I used the time I would have spent in class for other homework instead of study on this class materials. Honestly, I only signed up to give me 2 more hours of work per week.”
- “I feel like [the professor] didn’t quite get the gist of the experimental group. He came with a prepared lecture and it was harder to ask him questions and get satisfactory answers even with only 4 people in our group. I like the question/answer format better w/ the professor highlighting important points along the way.”
- “The book was not sufficient to understand the material.”
- “I felt lost in the experimental group and didn’t grasp the material because I didn’t ask the right questions.”
- “I felt more accountable to study so I could come with questions to ask. (i.e. I studied more).”
- “I don’t think the book is very helpful and having the professor lecture would have been more beneficial.”

4.5.5. Summary

The general tone from the students who participated in the experimental groups was positive. The following is a list of noteworthy responses:

- Common question 3: 98% of all experimental participants noted they liked having the opportunity to ask questions and receive immediate feedback.
- Common question 4: 88% of participants reported the instruction they received was either as good as, or better than, what they normally receive.
- Common question 7: 82% of all students reported they would participate in a similar class again.
- Common questions 8 and 9: 86% of students felt that during the experimental instruction they were able to have more interaction with the instructor than they would have had in a normal lecture, and 100% of those students felt the increased interaction was beneficial to their learning.
- Quality Systems question 8: 61% of students in the experimental group reported greater excitement to attend the experimental lectures than normally taught lectures.
- Polymer Processing Question 20: 100% of students reported that the experimental instruction required them to take more responsibility for their learning.

- Polymer Processing question 26: 79% of students reported spending more time outside of class reading and studying course material than they normally would have.
- Manufacturing Automation question 21: 73% of participants reported the experimental instruction encourage them to ask questions.

Of the 46 students who participated in the experimental instruction, 32 provided comments on their experiences. When organized the comments fall into five topic areas. These topics deal with: required maturity level, feelings of responsibility, increased interaction with instructor and classmates, wanting more instruction, and inadequacy of course text/materials.

Table 4-19 tallies how many comments fell into each area. Based on the results from the experimental-only portion of the post-survey the researcher feels confident that the students in the experimental groups had more positive attitudes than the control groups.

Table 4-19: Student Comments by Topic

	Number of Comments
Required Maturity Level	6
Feelings of Responsibility	6
Increased interaction with instructor and classmates	6
Wanting more instruction	6
Inadequacy of course text/materails	3
Other	5

4.6. Results from Professor Surveys

There are always two sides to every story. Up to this point, data collection efforts have focused on the students and how they responded to the experimental instruction. To enable the researcher to better understand the experience from the perspective of the instructor a short survey was administered to each professor. Each of the 13 questions contained in the survey and the responses from each professor are recorded below. Unless otherwise noted, the instructors were asked to answer each question using a ten point scale, ten being the highest, most positive, or most affirmative answer.

1. Do you feel that the students' needs were fulfilled during the experimental treatment?

   Quality Systems: 8   Polymer Processing: 8   Manufacturing Automation: 9

2. During the treatment, did you feel like you were able to cover the appropriate material?

Quality Systems: 8 Polymer Processing: 8 Manufacturing Automation: 8

3. Do you feel that the question and answer instruction was more challenging than your normal lectures?

   Quality Systems: 9 Polymer Processing: 9 Manufacturing Automation: 4

4. Would you consider instead of teaching one large group two times per week, teaching two smaller groups one time per week? (1 being very apprehensive, 10 being no apprehension).

   Quality Systems: 10 Polymer Processing: 9 Manufacturing Automation: 2

5. What outcomes from the study would persuade you to adopt this method (question and answer instruction)? Please list:

   Quality Systems:
   -Responsibility for learning taken by student
   -Better retention of material
   -More interest in material by students
   Polymer Processing:
   -Good student success
   -Student willingness
   Manufacturing Automation:
   -If it motivated or caused the students to spend more time studying on their own.

6. Did you feel in general that you were able to answer the students' questions satisfactorily?

   Quality Systems: 8 Polymer Processing: 9 Manufacturing Automation: 7

7. Do you feel that this method required greater knowledge than normal lecturing?

   Quality Systems: 10 Polymer Processing: 9 Manufacturing Automation: 5

8. Do you feel that this method required greater preparation than normal lecturing?

   Quality Systems: 8 Polymer Processing: 5 Manufacturing Automation: 5

9. Without regard to student performance which teaching method did you enjoy most?

   Quality Systems/Polymer Processing/Manufacturing Automation: Q&A

10. Which method do you feel the students enjoyed more?

    Quality Systems/Polymer Processing/Manufacturing Automation: Q&A

11. By which method do you think students learned more?

    Quality Systems/Polymer Processing: Q&A
    Manufacturing Automation: Normal Lecture

12. Would you consider applying the question and answer method to all of your classes?

    Quality Systems: Yes
    Polymer Processing: Yes
    Manufacturing Automation: No

13. Do you feel students in the experimental group took more responsibility for their learning than in normal lecture?

    Quality Systems: 6   Polymer Processing: 9   Manufacturing Automation: 3

4.6.1. Summary

Looking at the responses from this survey, it is apparent that the experiences of the professors of the three classes were not uniform. The method was met with much more optimism in the Quality Systems and Polymer Processing courses than in Automation. The professors from Quality Systems and Polymer Processing both indicated a willingness to consider implementing the experimental instruction in all their classes. They both felt that the students in the experimental group learned more than the control group. They also indicated the question and answer method required greater preparation and more knowledge than a normal lecture. According to the experience of the Automation professor, the preparation and knowledge needed to teach using the experimental instruction was not much different than normal class. The Manufacturing

Automation instructor felt that the control group learned more and indicated extreme apprehension to implement this method in other classes.

Despite differences, there were also several questions to which all three professors responded similarly. All three professors felt they were able to meet students' needs, answer questions satisfactorily, and cover appropriate material using the question and answer sessions. When asked which method they thought students enjoyed more all three responded "The question and answer group." Also, all three professors indicated they enjoyed the question and answer method more than normal lecturing.

4.7. Researcher Observations

Throughout the experiment, the researcher attended the experimental lectures in each of the three classes to make observations. It was very interesting to witness the interactions between students and teacher and between students and students. Generally, students appeared to enjoy and even thrive on the interaction with the professors. The students would ask a question, the professor would provide an answer or explanation, and the students would often reply with follow-up questions. Often, students rephrased answers to ensure they understood correctly. Not uncommonly, students would answer other students' questions.

One common occurrence in all the classes was the manner in which the discussion could jump from topic to topic. As questions were asked and answers supplied, students began to make connections to other subject areas. The result was a discussion that jumped from related topic to related topic. A class could begin with a discussion of one topic, move on to several others, and then bounce back to the original topic when the immediate discussion provoked new questions about the original topic. Also, students would bring up previous topics to help clarify or explain current questions.

As an outside observer, it was apparent that students were actively engaged in organizing information and forming connections within their individual knowledge frameworks. As discussed in chapter 2, constructivist theory suggests that learning takes place as students incorporate information into knowledge structures. As questions were asked and answers provided students appeared to rearrange and make new connections between different pieces of information. For instance, in the Polymer Processing course several questions were asked regarding plasticizers. The teacher answered the questions, and the discussion moved on. Several minutes later, the discussion had moved to environmental stress cracking and crazing in plastics. One student raised his hand and asked if the reason the dashboard in his car had cracked was that it had lost its plasticizers. What occurred was this student was able to understand why his dashboard had cracked after having incorporated information about plasticizers and cracking into his knowledge framework. This type of experience was not uncommon during the experimental sessions in all three classes.

The researcher also noted that each professor was able to implement the question and answer format to varying degrees. Based upon observations, the experimental instruction in the Quality Systems and Polymer Processing courses followed the question and answer concept much more closely than was accomplished in the Manufacturing Automation class. Based upon observations, the critical mass of students needed to successfully employ this method was about ten. With class sizes of five or less it was very difficult to have enough questions to fill the entire 50-minute class. For this reason, the experiment in the Manufacturing Automation class struggled to attain a steady state. When questions lulled, the professor tended to slip into lecture mode.

Also interesting was that the students in the Quality Systems and Polymer Processing courses tended to ask a larger portion of questions related to principles and concepts. The questioning in the Manufacturing Automation class focused almost exclusively on homework problems and computational procedures. Students in the Manufacturing Automation class frequently commented that the book was insufficient to understand how to calculate several of their assigned homework problems.

Attendance in the Quality Systems and Polymer Processing courses was very high for the experimental groups. However, the Manufacturing Automation course attendance levels were very poor. This was in part due to miscommunications between the researcher, professor and the students. Also the times allotted for the experimental sessions were difficult for many of the participants. The session that met at 2PM Fridays had the poorest attendance, usually 2 students, the Fridays at 7AM was slightly better with 3. The Tuesdays at 5PM session typically had 4 students. So, in a normal week, 9 of the 13 participants attended.

On several occasions in the Quality Systems and Polymer Processing courses, students asked questions until the bell at the end of the hour. The engagement level of the students was high and typically every student asked at least one question. Students in the Polymer Processing experimental group enjoyed the question and answer format so much that they inquired whether it would be possible to continue the sessions throughout the remainder of the semester even though the experiment had concluded.

4.8. Results Summary

Very briefly, the research results will be condensed. In review, this research set out to answer two research questions: 1) is there a difference in student learning related to the use of traditional lecture or inquiry-based instructional methods in technical classes, and 2) is there a difference in student attitude towards course material related to the use of traditional lecture or inquiry-based instructional methods in technical classes.

The table below is intended to condense the findings from each class into one easy to understand table. The table shows the results from each of data source and whether the analysis of that source provided evidence to reject the associated our null hypothesis.

Table 4-20: Summary of Results

Course	Research Question	Data Source	Null Hypothesis Rejected?	
			Yes	No
Quality	Question 1	Pre/Post Test		✓
		Course Exam	✓	
	Question 2	Pre/Post Survey	✓	
		Experimental-Only Survey	✓	
Plastics	Question 1	Pre/Post Test	✓	
		Course Exam		✓
	Question 2	Pre/Post Survey	✓	
		Experimental-Only Survey	✓	
Automation	Question 1	Pre/Post Test		✓
		Course Exam		✓
	Question 2	Pre/Post Survey		✓
		Experimental-Only Survey	✓	

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Effect of Experimental Method on Student Learning

Two different measures were used to determine the effect of the experimental instruction on learning – pre- and post-tests, and results from a regular course exam. The experimental groups from the Quality Systems and Polymer Processing courses both performed significantly higher on at least one of these measures than did the corresponding traditional lecture group. The results from the Manufacturing Automation course showed no significance for either measure. Table 5-1 shows which measure indicated significance and the corresponding level.

Table 5-1: Learning Measure and Significance by Course

Courses	Measure	Significant favoring of Experimental group?	P-Value
Quality Systems	Pre/Post-Test	No	0.370
	Course Exam	**Yes**	**0.094**
Polymer Processing	Pre/Post-Test	**Yes**	**0.092**
	Course Exam	No	0.550
Manufacturing Automation	Pre/Post-Test	No	0.740
	Course Exam	No	0.340

5.2. Effect of Experimental Method on Student Attitude towards Subject Matter

The results from the pre- and post-surveys demonstrated a statistically significant improvement in attitude towards subject matter for the experimental groups in two of the three participating courses. In addition, the experimental-only survey showed that all three courses favored the inquiry instructional method over the traditional lecture method. Students in the Quality Systems course reported significantly better confidence than their control group counterparts, and students in the Polymer Processing course reported greater classroom involvement and satisfaction. Ninety-eight percent of all experimental participants (all three courses combined) reported to have liked the opportunity to ask questions and receive immediate feedback. Eighty-eight percent reported that the instruction in the experimental group was as good as, or better than, what they received in normal classes. Eighty-six percent reported to have had increased interaction with the instructor, and 100% of those students felt their learning benefited from the interaction. Statistically and qualitatively, the experimental instruction positively affected student attitudes towards course material.

The findings from this study show that the inquiry-based instruction was superior in improving student's learning and attitudes toward course material than traditional lecture-based instruction. Regarding learning, the experimental groups which met half as often as the control groups performed as good as and in two instances performed better than their respective control groups on all learning measures. Regarding attitude, the experimental groups for each class displayed better attitudes towards subject matter than their control groups. The dimension of attitude improvement ranged from: 1. Increased confidence; 2. improved class participation and satisfaction; and 3. better attendance.

One advantage offered by the inquiry-based experimental instruction is that it helped students feel more responsible for their learning. This outcome can be seen below in comments from students in each of the three courses.

- From the Quality Systems course: "I felt compelled to study outside of class."
- From the Polymer Processing course: "I was more concentrated on the readings and learning the material, because it was my responsibility to learn, rather than [the professor's] responsibility to teach me."
- From the Manufacturing Automation course: "I felt more accountable to study, so I could come with questions to ask. (i.e., I studied more)."

Because students took more responsibility for their learning, they were able to learn much of the course material on their own, outside of class. Instead of using class time to cover material from the book, the inquiry groups engaged in collaborative discussions. These discussions helped create an interactive environment where students felt more comfortable participating. The discussion topics were advanced, and gave students the opportunity to practice critical thinking skills.

The results of this study have revealed that the quality of the text is an important factor contributing to the success of this type of inquiry-based instruction. Several students in the Manufacturing Automation class felt the assigned textbook was insufficient to understand the material. In order for the inquiry-based question and answer sessions to work, faculty must provide high quality resources for the students to learn from.

When the instructors who participated were surveyed, two of the three indicated that the inquiry-based instruction was more challenging than normal lectures. The professor who did not feel that the inquiry-based instruction was more challenging taught the only class where students expressed frustration with the course text being insufficient. This suggests that when students were enabled by quality texts, and able to prepare outside of class, the inquiry-based instruction was more challenging. The professors in the classes, whose texts were adequate, encountered students prepared with challenging and thought provoking questions.

5.3. Substantiation of Results in Related Literature

Each course in this study experienced inquiry learning in a unique manner. This is evidenced in the varying results for each test method. Such variation is consistent with current literature. Two sources cited in the literature review, Jones (2003) and Felder (1997), found that inquiry-based instruction had no significant effect on student learning. However, the study by Chang and Mao (1999) showed the opposite. Their study showed that inquiry-based instruction has a significant effect on student learning. In light of the varying outcomes found in related literature, it is not surprising to see the results from this study varied from class to class.

Though the studies by Chang and Mao (1999), Felder (1997), and Jones (2003) do not all concur on the effect of inquiry-based instruction on learning as measured by standard criteria, they are consistent in the conclusion that inquiry learning had other beneficial and significant effects. All indicate a significant difference in student attitude when taught using principles of inquiry learning. This study is consistent with these findings. Attitude in the experimental groups towards subject matter was significantly different than that of the control groups. Table 5-2 below has been provided as a summary of claims made in the literature, and whether these claims can be confirmed based upon the results from this study.

Table 5-2: Literature Claims

Claims Made in Literature	Source	Confirmed?	By What Data?
Inquiry methods have no effect on student learning	Jones (2003), Felder (1997)	YES	-Pre/Post Test in Quality Systems and Manufacturing Automation classes. -Course Exam in Polymer Processing and Manufacturing Automation classes
Inquiry methods have a positive effect on student learning	Chang, Mao (1999)	YES	-Pre/Post Test in Polymer Processing class -Course Exam in Quality Systems class
Inquiry methods have a positive effect on student attitudes towards subject matter	Jones (2003), Felder (1997), Chang, Mao (1999)	YES	-Pre/Post Survey in Quality Systems and Polymer Processing classes -Experimental-Only Survey in all three classes.

5.4. Advantages and Concerns

This study has demonstrated that when students take a more active role in learning material on their own, less in-class instruction is needed. This finding is very intriguing, and is one of the most important discoveries of this study. However, of similar importance are the concerns the research has identified. These concerns are:

- Student uneasiness moving from two hours of instruction to one hour.
- What role does student maturity play in the success of this approach?
- Implementing the question and answer sessions will require significant upfront investment of time and effort as faculty rework lesson plans and select high quality texts and materials.
- Not all faculty will embrace this method. (Tremendous inertia behind traditional lecture approach.)
- Are the results from a 4-5 week intervention indicative of the true effect of a fulltime implementation?

Based on these concerns, it is clear that more research into the effects of an inquiry-based question and answer session on student learning and attitudes is needed.

However, it is also clear that this instructional approach could potentially offer tremendous advantage over the traditional lecture approach. If it is true that an inquiry-based question and answer session can replace a twice-a-week lecture and can achieve learning outcomes at least as good as current practices, there will be far reaching implications for students and faculty.

From the perspective of the student, the greatest advantage this method offers is that it helps students take more responsibility for their learning, and at the same time promotes positive attitudes about course material. So much of what we learn today in technical areas will soon be outmoded (NAE, 2004). Students who take more responsibility for their learning will be better equipped to continue learning throughout their careers and lifetime. Education is not about what you know – it is about what you can learn. By taking more responsibility for their learning, students are learning to learn.

Most faculty at most universities are faced with two important tasks. First, they are under pressure to conduct research and publish scholarly papers; and secondly, they are tasked with teaching numerous courses. Every hour spent teaching takes away from the time a professor could spend conducting research and vice versa. The inquiry-based instructional method studied in this research could help professors better achieve their two-fold charge. Upfront preparation of course materials may be more intense for inquiry-based instruction, but should eventually free up time for faculty to conduct more research, and/or take on a heavier course load.

Technical classrooms ought to be collaborative learning environments in which students can actively construct knowledge and achieve understanding of course material. To improve the learning in our universities, we must integrate and develop teaching methods to promote interaction between teacher and student. Wurdinger (2005) calls for new approaches to be tried in our schools when he states, “students need to be active learners and solve problems. Many are bored with lecture and other teaching formats that result in passive learning. They do not want to sit and listen to someone talk for entire periods. Society requires individuals to be active learners that are able to solve problems, so our schools should mirror what society expects” (p. 5-6). Part of the solution to improving education is promoting teaching paradigms which encourage student participation and interaction with their peers and their teachers.

Lecture-based instruction promotes memorization of facts and principles and often fails to create an ability to practically apply what has been learned. The study reported herein, has shown that the use of an inquiry-based question and answer sessions helped create a more interactive environment and encouraged students take more responsibility for their own learning. For example, 100% of the experimental group in the Polymer Processing class reported that the inquiry-based instruction required them to take more responsibility for their learning. Seventy-nine percent of the experimental group in the Polymer Processing course also reported to have spent more time outside of class studying than normal. Eighty-six percent of all students felt that they had more interaction with their instructors. With respect to responsibility for learning, Bok (2006) states, “Lectures demand little of [students] except sitting still. No preparation for class is necessary” (p. 125). To teach students how to learn, it is imperative that we teach them to take more responsibility for their learning. The inquiry method explored in this study encourages students to do just that.

There are several other methods educators have espoused in an effort to help students learn to learn. One common approach is student mentoring. In a mentoring relationship, students are given challenging assignments designed to make them struggle and learn on their own. Professors then act as coaches, lend advice, and give encouragement, only after significant effort has been expended by the student in solving the problem. The biggest drawback to mentoring is that it is only effective in one-on-one situations or in small groups. It is not easily scaleable.

Self-grading is another innovative technique educators have tried in an effort to help students take more responsibility for their learning. A study involving self-grading reported that students felt more motivated to learn and took more responsibility for their learning (Strong, et. al, 2004). However, such arrangements can often suffer from grade inflation as some students exploit the system. They also have no inherent provision for creating opportunity for increased interaction with the instructor.

There are countless techniques educators can choose from when trying to improve the learning in their classrooms. When choosing which methods to consider, they must weigh the pros and cons of each. The findings from this study have demonstrated that inquiry-based learning in technical classrooms can lead to improved student learning and attitude. This is not to suggest that inquiry-based learning is a complete or universal solution to improve the learning environment in technical undergraduate classrooms. More than anything, this research should demonstrate that innovative approaches to learning and teaching can offer advantages over traditional lecture-based learning. Should the traditional lecture be done away with? No. But perhaps by integrating principles of inquiry-based learning into lectures, the experience can be enhanced.

Vygotsky (Byrnes, 1996) taught that the key to learning is social interaction. Whatever approach educators take to improve learning they should consciously select those techniques that foster student responsibility and increased interaction.

5.5. Recommendations

The effects of an inquiry-based question and answer session on student learning and attitudes needs more research. It would be fascinating to undertake a more extensive study of the long-term effects of using this method. This study was conducted in three technical undergraduate classes over the space of 4-5 weeks. To understand the true effect of this instructional method, further research should be done over an extended time period.

It would also be interesting to understand the effect of using this instructional method in conjunction with other techniques intended to promote student ownership for learning. One student from the experimental group commented, "I would have liked more guidance – maybe study questions/topics, or two meeting times. I love the format, but I feel it is still missing something." To fill this perceived void, any number of other techniques could be used in conjunction with the question and answer sessions. Students could be assigned outside peer discussion groups, they could be given extensive study questions to prepare outside of class, or they could even meet with TAs once-a-week for a review of textbook material.

The possibilities for further research are extensive. Much more work is needed to better understand how best to use and structure inquiry-based principles in technical classrooms. To achieve a better understanding of the effects of the inquiry-based question and answer sessions the following list of ideas for further study and research might be considered:

- What is the effect of the inquiry-based question and answer format on knowledge retention? Is there a difference in knowledge retention after six months, a year, five years, etc.?
- What is the effect of combining the once-a-week question and answer sessions with a once-a-week peer discussion group?
- What would be the effect of implementing this method for an entire semester?
- What would be the effect of using the first half of a semester to teach foundational principles and skills, and the second half being question and answer sessions?
- What other teaching paradigms could be used to compliment the question and answer format?

REFERENCES

Biggs, J.B. (1999). *Teaching for Quality Learning at University*. St. Edmundsbury Press, Bury St. Edmunds, UK.

Bloom, Benjamin, S. (1976). Human *Characteristics and School Learning*. New York, New York: McGraw-Hill.

Bok, D. (2006). *Our Underachieving Colleges*. Princeton, New Jersey: Princeton University Press.

Donovan, S., Bransford, J., Pelleigrino, J. (1999). *How people learn: bridging research and practice*. Washington, D.C.: National Academy Press.

Britton, J. (1982). *Talking*. In G. M. Pradl (Ed.), *Prospect and retrospect: Selected essays of James Britton* (pp.112-122). Montclair, NJ: Boynton/Cook.

Byrnes, J. P. (1996). *Cognitive Development and Learning in Instructional Contexts. Boston*, MA: Allyn and Bacon.

Cabal, A. B. (1993). *The University as an Institution Today*. Ottawa, Canada: International Development Research Centre.

Chang, C., Mao, S. (1999). Comparison of Taiwan Students' Outcomes with Inquiry-Group Versus Traditional Instruction. *The Journal of Educational Research*. July/Aug 1999 92(6), 340-346.

Courts, P.L., & McInerny, K. H. (1993). *Assessment in higher education: Politics, pedagogy, and portfolios*. Westport, CT: Praeger.

Educational Policies Commission (EPC). (1961). *The central purpose of American education*. Washington DC: National Education Association

Elshorbagy, A., & Schonwetter, D. J. (2002). Engineer morphing: Bridging the gap between classroom teaching and the engineering profession. *International Journal of Engineering Education*, 18(3), 295-300.

Felder, R. M. (1997). A Longitudinal Study of Alternative Approaches to Engineering Education: Survey of Assessment Results. *Frontiers in Education Conference, 1997. 27th Annual Conference. 'Teaching and Learning in an Era of Change'*. Vol. 3, 1284-1289.

Felder, R. M. (2006). Teaching Engineering in the 21st Century With a 12th Century Teaching Model: How Bright is That?. *Chemical Engineering Education*, 40(2), 110-113.

Flynn, P. (1995). Global competition and education: Another sputnik? *The Social Studies*, 86 (2), 53-55.

Friedman, Thomas, L. (2005). *It's a flat world after all*. New York Times Magazine, April 3, 2005, p. 32.

Grabe, M., Grabe, C. (2000). *Integrating the Internet for Meaningful Learning*. Boston, MA: Houghton Mifflin.

Guion, L. A. (2002). Triangulation: Establishing the validity of qualitative studies (EDIS Publication No. FCS6014). Gainesville, FL: University of Florida, Cooperative Extension Service.

Hebrank, M. (2000). *Why Inquiry-Based Teaching and Learning in the Middle School Science Classroom?* [On-line]. Available: www.biology.duke.edu/cibl/inquiry/why_inquiry_in_ms.htm

Jarvis, P., Holford, J., Griffin, C. (2003). *The theory and practice of learning. 2nd Ed*. Sterling, VA: Kogan Page Limited.

Jensen, E. (2005). *Teaching with the Brain in Mind* (2nd Edition). Alexandria, VA: Association for Supervision and Curriculum Development.

Jones, G. M. (2003). Relationship Between Inquiry-Based Teaching and Physical Science Standardized Test Scores. *School Science and Mathmatics*. 103(7) p.345-350

Martin, R. Sexton, C. Gerlovich, J. (2002). *Teaching Science for all Children* (2nd Ed.). Boston, MA: Allyn and Bacon.

Milton, O. (1982). Will That Be on the Final?. *Paper presented at the Annual Meeting of the American Psychological Association* (Washington, DC, August 23-27, 1982).

National Academy of Engineering (NAE). (2004). *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: National Academy Press.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Rivard, L.P and Straw, S.B. (2000). The effect of talk and writing on learning science: An exploratory study. *Science Education*, 84 (5), 566.

Snedecor, G. and Cochran, W. (1989). *Statistical Methods, 8th Ed*. Iowa: Iowa State University Press.

State University of New York. 2006). *Research Methods: Triangulation in Research.* [On-line]. Available: http://www.tele.sunyit.edu/traingulation.htm

Tobin, K. & Tippins, D. (1993). Constructivism as a Referent for Teaching and Learning. In Tobin, K. (Ed), The Practise of Constructivism in Science Education. Hillsdale, NJ; Lawrence Erlbaum Associates.

Ward, C. (2007). Interview with Carol Ward, BYU Professor of Sociology. January 25, 2007.

Wurdinger, S.D. (2005). *Using Experiential Learning in the Classroom*. Lanham, MD: Scarecrow Education.

Yergin, D. & Stainslaw, J. (2002). *The Commanding Heights: The battle for the world economy.* New York: Touchstone Publishing.

Zevin, J. (1973, April). Training Teachers in Inquiry. *Social Education*, 37, 310-316.

APPENDICES

Appendix A: Pre- and Post- Surveys

Quality Systems Pre-Survey
Name__________________________ Meeting Time_________________________

MFG 340 DOE Pre-Survey & Test

Please Read Before Starting:
Results from this test will in no way effect your course grade. Rather than try to guess the correct answer, please mark "I do not know" on questions where you have no prior knowledge. The intent of this test is to determine what is already known regarding DOE thereby creating a baseline for our research. Individual results from this test will remain confidential.

Before you start the test, we would like for you to complete a brief survey about you and your experiences with studying technical subject matter. Your answers are completely confidential. Thank you for participating in this survey.

Participant survey

1. Age: ________
2. Gender (Please circle one): Male Female
3. Year in School (Please circle one): Sophomore Junior Senior
4. I most prefer to learn (Rank mark your first 3 preferences by numbering them 1-3):

    ____ On my own (self directed)

    ____ In group settings

    ____ From books

    ____ Through experience (hands on)

    ____ Through hearing

    ____ Through experimentation (lab work)

    ____ Help lab or tutor

5. I would describe my understanding of statistical principles as (Circle one):
    a. Very good
    b. Good
    c. Neither good nor bad
    d. Poor
    e. Extremely poor

6. How would you describe your confidence in using statistical concepts to understand and improve manufacturing processes? (Please circle one.)
    a. Very confident
    b. Confident
    c. Neutral
    d. Unconfident
    e. Very unconfident

7. Based on your experience in methods and/or statistics courses, how would you describe your ability to advantageously apply information learned to real world situations? (Please circle one.)
    a. Always able
    b. Often able
    c. Sometimes able
    d. Rarely able
    e. Never able

8. If you encounter a problem or an assignment that is challenging to you, how long do you work before seeking help? (Please circle one.)
    a. I usually never seek help, I work through it until I get it
    b. I usually never seek help, and rarely gain a solid understanding of the related material.
    c. If I know the problem or assignment will be challenging I rarely make an attempt without assistance
    d. I usually work a until I get stuck and then seek out help
    e. I do as much as I can on my own, but usually do not seek out help

9. When I find myself floundering or falling behind in a class at school, I (please circle one):
    a. Work harder to learn the material on my own, and am usually successful
    b. Work hard to learn the material on my own, but often end up falling farther behind
    c. Try to learn the material on my own, but often rely on labs, tutors, or help sections to learn the material.
    d. If I have trouble with the material I immediately seek additional help from teachers, friends, help labs, etc.
    e. If I have trouble with material I usually lose interest in the subject, and end up doing the minimum to get by.

10. When you seek out help and get it, how useful is it to you? (Please circle one)
    a. Always useful
    b. Often useful
    c. Sometimes useful
    d. Never useful
    e. I have never sought out help

Quality Systems Post Survey

Name________________________ Meeting Time_________________________

MFG 340 DOE Survey and Post-Test

Please Read Before Starting:
Results from this test will in no way effect your course grade. Individual results from this test will remain confidential.

Participant survey

1. For every hour of class instruction, I spent ___ hours outside of class learning/studying DOE material. (Circle one):
    a. 0
    b. <1
    c. 1-2
    d. 2-3
    e. >3

2. The instruction I received in class has increased my confidence in my ability to apply principles of DOE to real world applications. (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly agree

3. How would you describe your confidence in using statistical concepts to understand and improve manufacturing processes? (Circle one):
    a. Very confident
    b. Confident
    c. Neutral
    d. Unconfident
    e. Very unconfident

4. Based on your experience and knowledge of DOE, how would you describe your ability to correctly apply information learned to real world situations? (Circle one):
    a. Always able
    b. Often able
    c. Sometimes able
    d. Rarely able
    e. Never able

5. If given the opportunity, I would (Circle one):
    a. Participate in the control group again
    b. Participate in the experimental group again

c. Participate in the control group rather than the experimental group
d. Participate in the experimental group rather than the control group

6. My understanding of statistical principles is (Circle one):
    a. Very good
    b. Good
    c. Neither good nor bad
    d. Poor
    e. Extremely poor

7. (Control Group Only) Please select the answer that best describes your attitude towards class during the DOE instruction. (Circle one):
    a. Excited for class
    b. Somewhat excited for class
    c. Neutral
    d. Somewhat loathed class
    e. Loathed class

Questions 8-19 are for the Experimental Groups Only. If you participated in the regular class lecture please continue on to the post-test on page 4.

8. As compared to regular class instruction, I was _______ about class during the experimental instruction. (Circle one):
    a. Much more excited
    b. More excited
    c. Same excitement
    d. Less excited
    e. Much less excited

9. I liked the question/answer class format. (Circle one):
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly agree

10. I feel I would have learned more about DOE if I had <u>not</u> participated in the experimental group. (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree
    f. For all answers why?____

11. Regarding the “Test Group Study Questions,” I (Circle one):
    a. went through every question thoroughly
    b. went through most of the questions thoroughly
    c. went through some of the questions thoroughly
    d. did not use them

12. I liked having the opportunity to ask questions about material I did not understand and to receive immediate feedback. (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly agree

13. I find that participating in the study (Circle one):
    a. helped my learning
    b. adversely affected my learning
    c. was not much different than a normal class

14. The experimental group have been more helpful if (Circle one):
    a. you were assigned to an outside discussion group where you discussed readings and course material with your peers
    b. you were required to report on the amount of the reading assignment you completed
    c. you were given more study questions
    d. the readings were coupled with homework problems

15. As compared to other learning experiences regarding a technical subject do you feel that during the experimental format (Circle one):
    a. you were better appraised of your progress and understanding of material
    b. you were less appraised of your progress and understanding of material
    c. no difference from what I am used to

16. T / F Given the opportunity, I would participate again in similar structured classes.

17. T / F I feel that I had more interaction with the teacher than I would have had in a normal lecture.

18. Y / N If you felt you had more interaction, do you feel that it was beneficial to your learning?

19. Please use the space below for comments:

Polymer Processing Pre-Survey
Name_________________________

MFG 355 Pre-Survey

Please Read Before Starting:
Results from this test will in no way effect your course grade. Rather than try to guess the correct answer, please mark "I do not know" on questions where you have no prior knowledge. The intent of this test is to determine what is already known about plastics thereby creating a baseline for our research. Individual results from this test will remain confidential.

Before you start the test, we would like for you to complete a brief survey about you and your experiences with studying technical subject matter. Your answers are completely confidential. Thank you for participating in this survey.

Participant survey

11. Age: _______

12. Gender (Please circle one): Male Female

13. Year in School (Please circle one): Sophomore Junior Senior

14. I most prefer to learn (Rank mark your first 3 preferences by numbering them 1-3):

    ____ On my own (self directed)

    ____ In group settings

    ____ From books

    ____ Through experience (hands on)

    ____ Through hearing

    ____ Through experimentation (lab work)

    ____ Help lab or tutor

15. I would describe my understanding of plastics as (Circle one):
    a. Very good
    b. Good
    c. Neither good nor bad
    d. Poor
    e. Extremely poor

16. How would you describe your confidence in using your knowledge of plastics to understand and improve manufacturing processes? (Circle one):
    a. Very confident
    b. Confident

c. Neutral
d. Unconfident
e. Very unconfident

17. Please select the answer that best describes your attitude towards this course in plastics. (Circle one):
    a. Excited for class
    b. Somewhat excited for class
    c. Neutral
    d. Somewhat dreading class
    e. Dreading class

18. If you encounter a problem or an assignment that is challenging to you, how long do you work before seeking help? (Please circle one.)
    a. I usually never seek help, I work through it until I get it
    b. I usually never seek help, and rarely gain a solid understanding of the related material.
    c. If I know the problem or assignment will be challenging I rarely make an attempt without assistance
    d. I usually work a until I get stuck and then seek out help
    e. I do as much as I can on my own, but usually do not seek out help

19. When I find myself floundering or falling behind in a class at school, I (please circle one):
    a. Work harder to learn the material on my own, and am usually successful
    b. Work hard to learn the material on my own, but often end up falling farther behind
    c. Try to learn the material on my own, but often rely on labs, tutors, or help sections to learn the material.
    d. If I have trouble with the material I immediately seek additional help from teachers, friends, help labs, etc.
    e. If I have trouble with material I usually lose interest in the subject, and end up doing the minimum to get by.

20. When you seek out help and get it, how useful is it to you? (Please circle one)
    a. Always useful
    b. Often useful
    c. Sometimes useful
    d. Never useful
    e. I have never sought out help

21. Rate the accuracy of this statement. I focus my studies only on material that will be tested.
    a. Strongly agree
    b. Agree
    c. Somewhat agree

d. Disagree
e. Strongly Disagree

22. Rate the accuracy of this statement. My number one priority is to get the best grade in a class that I can.
    a. Strongly agree
    b. Agree
    c. Somewhat agree
    d. Disagree
    e. Strongly Disagree

23. Rate the accuracy of this statement. My number one priority is to achieve a real understanding of course material.
    a. Strongly agree
    b. Agree
    c. Somewhat agree
    d. Disagree
    e. Strongly Disagree

24. Rate the accuracy of this statement. I often finish a class with a collection of facts and information but lack an understanding of how to apply it.
    a. Strongly agree
    b. Agree
    c. Somewhat agree
    d. Disagree
    e. Strongly Disagree

Polymer Processing Post-Survey
Circle One: Control Group / Experimental Group

Name__________________________ Meeting Time_________________________

MFG 355 Survey and Post-Test

Please Read Before Starting:
Results from this test will in no way effect your course grade. Individual results from this test will remain confidential.

Participant survey

1. What is your major? _________________________

2. For every hour of class instruction, I spent ___ hours outside of class learning/studying course material. (Circle one):
    a. 0
    b. <1
    c. 1-2
    d. 2-3
    e. >3

3. The instruction I received in class has increased my confidence in my ability to apply principles relating to plastics materials to real world applications. (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

4. How would you describe your confidence in using concepts learned in this class to improve a plastics manufacturing process? (Circle one):
    a. Very confident
    b. Confident
    c. Neutral
    d. Unconfident
    e. Very unconfident

5. If given the opportunity, I would (Circle one):
    a. Participate in the control group again
    b. Participate in the experimental group again
    c. Participate in the control group rather than the experimental group
    d. Participate in the experimental group rather than the control group

6. I have learned a lot in this class (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

7. How do you feel about the instruction received in this class? The instruction was (Circle one):
    a. Significantly Enlightening
    b. Enlightening
    c. Barely better than the book
    d. Disappointing

8. Did lectures extend your knowledge beyond the textbook?
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

9. How do you feel about coming to this class
    a. Very excited
    b. Somewhat excited
    c. Not sure
    d. Unexcited
    e. Very Unexcited

10. Do you feel that all of your questions regarding course content have been answered during class?
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

11. Do you feel like some parts of class discussion were unnecessary?
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

12. I feel that my questions have been answered:
    a. Very satisfactory
    b. Satisfactory

c. Not sure
d. Somewhat unsatisfactory
e. Unsatisfactory

13. In an average class period I have asked
    a. 0-1 questions
    b. 1-3 questions
    c. 3+ questions

14. Did you always attend lecture?
    a. Never missed
    b. Missed 1 time
    c. Missed 2 times
    d. Missed 3 or more times

15. Do you feel you got your money's worth from this class?
    a. Yes
    b. No

16. Did you attend class more because you enjoyed class or you felt that if you missed class you would fall behind?
    a. Enjoyed class
    b. Fear of falling behind

Experimental Groups Only. If you participated in the regular class lecture please continue on to the post-test.

17. I liked the question/answer class format. (Circle one):
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

18. I feel I would have learned more about plastics if I had not participated in the experimental group. (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

    For all answers
    why?____

19. I liked having the opportunity to ask questions about concepts I did not understand and to receive immediate feedback. (Circle one):

a. Strongly agree
b. Agree
c. Not sure
d. Disagree
e. Strongly disagree

20. Participating in the study required me to take more responsibility for my learning.
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

21. I find that participating in the study (Circle one):
    a. helped my learning
    b. adversely affected my learning
    c. was not much different than a normal class

22. The experimental group would have been more helpful if (Circle one):
    a. you were assigned to an outside discussion group where you discussed readings and course material with your peers
    b. you were required to report on the amount of preparation you performed outside of class
    c. you were given specific study questions
    d. the readings were coupled with homework problems

23. Did you find this format encouraged you to ask the questions you had?
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

24. As compared to other learning experiences regarding a technical subject, do you feel that during the experimental format (Circle one):
    a. you were better appraised of your progress and understanding of material
    b. you were less appraised of your progress and understanding of material
    c. no difference from what I am used to

25. Did you feel that there were times when you did not have questions, and no one else did either?
    a. Always
    b. Sometimes
    c. Never

26. T / F During the study I spent more time outside of class reading and studying course material than I otherwise would have?

27. T / F Given the opportunity, I would participate again in similar question-oriented classes.

28. T / F I feel that I had more interaction with the teacher than I would have had in a normal lecture.

29. Y / N If you felt you had more interaction, do you feel that it was beneficial to your learning?

Please use the space below for any comments you would like to add about your experience during this study:

Manufacturing Automation Pre-Survey
Name________________________

MFG 434 Pre-Survey

Please Read Before Starting:
Results from this test will in no way affect your course grade. Rather than try to guess the correct answer, please mark "I do not know" on questions where you have no prior knowledge. The intent of this test is to determine what is already known about automation thereby creating a baseline for our research. Individual results from this test will remain confidential.

Before you start the test, we would like for you to complete a brief survey about you and your experiences with studying technical subject matter. Your answers are completely confidential. Thank you for participating in this survey.

Participant survey

1. Age: _______

2. Gender (Please circle one): Male Female

3. Year in School (Please circle one): Sophomore Junior Senior

4. I most prefer to learn (Rank mark your first 3 preferences by numbering them 1-3):

    ____ On my own (self directed)

    ____ In group settings

    ____ From books

    ____ Through experience (hands on)

    ____ Through hearing

    ____ Through experimentation (lab work)

    ____ Help lab or tutor

5. I would describe my understanding of automation as (Circle one):
    a. Very good
    b. Good
    c. Neither good nor bad
    d. Poor
    e. Extremely poor

6. How would you describe your confidence in using your knowledge of automation to understand and improve manufacturing processes? (Circle one):
    a. Very confident
    b. Confident
    c. Neutral
    d. Unconfident
    e. Very unconfident

7. Please select the answer that best describes your attitude towards this course in automation. (Circle one):
    a. Excited for class
    b. Somewhat excited for class
    c. Neutral
    d. Somewhat dreading class
    e. Dreading class

8. If you encounter a problem or an assignment that is challenging to you, how long do you work before seeking help?
    a. I work through it alone until I get it no matter how long it takes.
    b. I will work on a problem for about an hour and then I give up.
    c. I will work on a problem for about an hour and then seek out help
    d. If I know I am going to be stuck I get help immediately.
    e. If I know I am going to be stuck I just skip the problem and go on to the next one.

9. When I find myself floundering or falling behind in a class at school, I:
    a. Work harder to learn the material on my own, and am usually successful.
    b. Work hard to learn the material on my own, but often end up falling farther behind.
    c. Try to learn the material on my own, but often rely on labs, tutors, or help sections to learn the material.
    d. If I have trouble with the material I immediately seek additional help from teachers, friends, help labs, etc.
    e. If I have trouble with material I usually lose interest in the subject, and end up doing the minimum to get by.

10. When you seek out help and get it, how useful is it to you?
    a. Always useful
    b. Often useful
    c. Sometimes useful
    d. Never useful
    e. I have never sought out help

11. Rate the accuracy of this statement. “I focus my studies only on material that will be tested.”
    a. Strongly agree
    b. Agree
    c. Somewhat agree
    d. Disagree
    e. Strongly Disagree

12. Rate the accuracy of this statement. “My number one priority is to get the best grade in a class that I can.”
    a. Strongly agree
    b. Agree
    c. Somewhat agree
    d. Disagree
    e. Strongly Disagree

13. Rate the accuracy of this statement. “My number one priority is to achieve a real understanding of course material.”
    a. Strongly agree
    b. Agree
    c. Somewhat agree
    d. Disagree
    e. Strongly Disagree

14. Rate the accuracy of this statement. “I often finish a class with a collection of facts and information but lack an understanding of how to apply it.”
    a. Strongly agree
    b. Agree
    c. Somewhat agree
    d. Disagree
    e. Strongly Disagree

Manufacturing Automation Post-Survey
Circle One: Control Group / Experimental Group

Name__________________________   Meeting Time_________________________

MFG 434 Survey and Post-Test

Please Read Before Starting:
Results from this test will in no way effect your course grade. Individual results from this test will remain confidential.

Participant survey

1. For every hour of class instruction, I spent ___ hours outside of class learning/studying course material. (Circle one):
    a. 0
    b. <1
    c. 1-2
    d. 2-3
    e. >3

2. The instruction I received in class has increased my confidence in my ability to apply principles relating to automation to real world applications. (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

3. How would you describe your confidence in using concepts learned in this class to improve a manufacturing process? (Circle one):
    a. Very confident
    b. Confident
    c. Neutral
    d. Unconfident
    e. Very unconfident

4. If given the opportunity, I would (Circle one):
    a. Participate in the control group again
    b. Participate in the experimental group again
    c. Participate in the control group rather than the experimental group
    d. Participate in the experimental group rather than the control group

5. I have learned a lot in this class (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

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    c. Barely better than the book
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7. Did lectures extend your knowledge beyond the textbook?
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    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

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    a. Very excited
    b. Somewhat excited
    c. Not sure
    d. Unexcited
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9. Do you feel that all of your questions regarding course content have been answered during lecture?
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

10. Do you feel like some parts of lecture were unnecessary?
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

11. I feel that my questions have been answered:
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    c. Not sure
    d. Somewhat unsatisfactory
    e. Unsatisfactory

12. In an average class period I have asked
    a. 0-1 questions
    b. 1-3 questions
    c. 3+ questions

13. Did you always attend lecture?
    a. Never missed
    b. Missed 1 time
    c. Missed 2 times
    d. Missed 3 or more times

14. Do you feel you got your money's worth from this class?
    a. Yes
    b. No

15. Did you attend class more because you enjoyed class or you felt that if you missed class you would fall behind?
    a. Enjoyed class
    b. Fear of falling behind

Experimental Groups Only. If you participated in the regular class lecture please continue on to the post-test.

16. I liked the question/answer class format. (Circle one):
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly agree

17. I feel I would have learned more about automation if I had <u>not</u> participated in the experimental group. (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

    For all answers why?____

18. I liked having the opportunity to ask questions about concepts I did not understand and to receive immediate feedback. (Circle one):
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly agree

19. I find that participating in the study (Circle one):
    a. helped my learning
    b. adversely affected my learning
    c. was not much different than a normal class

20. The experimental group would have been more helpful if (Circle one):
    a. you were assigned to an outside discussion group where you discussed readings and course material with your peers
    b. you were required to report on the amount of the reading assignment you completed
    c. you were given specific study questions
    d. the readings were coupled with homework problems

21. Did you find this format encouraged you to ask the questions you had?
    a. Strongly agree
    b. Agree
    c. Not sure
    d. Disagree
    e. Strongly disagree

22. As compared to other learning experiences regarding a technical subject, do you feel that during the experimental format (Circle one):
    a. you were better appraised of your progress and understanding of material
    b. you were less appraised of your progress and understanding of material
    c. no difference from what I am used to

23. T / F Given the opportunity, I would participate again in similar question-oriented classes.

24. T / F I feel that I had more interaction with the teacher than I would have had in a normal lecture.

25. Y / N If you felt you had more interaction, do you feel that it was beneficial to your learning?

26. Please use the space below for comments:

Appendix B: Pre- and Post-tests

Quality Systems Systems Pre/Post-test

1. In a 2^2 DOE design, the base of 2 refers to the number of levels, and the 2 exponent refers to the number of __________.

2. When conducting experiments it is often valuable to perform multiple trials of each run. When speaking of trials it is important to distinguish between a replicate and a repeat. What is the difference?

3. A variance is:

    a. The sum of the square of the deviation of each observation of a sample from the sample average, divided by the sample size minus one.
    Variance = $\sum \frac{(X - \overline{X})^2}{n-1}$
    b. The absolute value of the difference of an observation of a sample from the sample average, divided by the sample size minus one.
    Variance = $\sum \frac{|X - \overline{X}|}{n-1}$
    c. The standard deviation of the sample average
    d. None of the above
    e. I do not know

4. If a measured *effect* in a DOE are outside the significance interval or decision limits,
    a. the factor involved is not significant
    b. `the factor involved is significant
    c. the *effects* do not determine factor significance
    d. none of the above
    e. I do not know

5. How do you calculate degrees of freedom (df)?
    a. df = number of runs – 1
    b. df = total number of observations – 1
    c. df = (number of runs) / (N-1)
    d. df = (number of observations per run – 1) X (# of runs)

6. True / False: A standard deviation is the square root of the variance.

7. True / False: In DOE experiments, both quantitative and qualitative variables can be used.

8. True / False: The intention of DOE is to determine what factors or factor interactions significantly influence the response variable or outcome.

9. Screening designs are used:
    a. To identify significant main effects
    b. When many factors must be evaluated
    c. To graphically display the DOE results
    d. None of the above
    e. I do not know

10. To say an interaction is confounded means:
    a. The effects of one interaction cannot be distinguished from those of another.
    b. The factors involved are the most significant
    c. The effects two interactions have combined to manifest the dominant variables
    d. None of the above
    e. I do not know

11. Main effects are defined as the:
    a. Difference in the average response between the high and low level of a factor
    b. Effects that have the greatest influence on outcomes
    c. Most significant factors
    d. None of the above
    e. I do not know

12. An interaction occurs when a particular combination of two factors
    a. Interact to negate their individual effects
    b. Does something unexpected from simply observing their main effects
    c. Neither (a) or (b) is correct
    d. I do not know

13. When designing your experiments how much of your resources should be allocated to your first experiment?
    a. As much as possible
    b. An amount that will leave adequate resources to complete all experiments
    c. DOE experiments typically require negligible resources
    d. I do not know

14. A DOE should not be conducted unless your process is:
    a. In control
    b. Out of control
    c. Void of any tampering
    d. I do not know

15. A reflection design is a method used to:
    a. Reflect on the results of the DOE and determine a path forward
    b. An experimental method used to encourage researchers to reflect on the robustness of their experimental procedures
    c. A method used to negate the effects of confounding
    d. I do not know

Polymer Processing Pre/Post-test

1. For a material to be classified as a plastic it <u>must</u> satisfy which of the following conditions:
   A) be made of petroleum based products
   B) consist of large molecules
   C) be easily moldable into a useful form
   D) can be remolded with the addition of heat
   E) a, c, and d
   F) both b and c
   G) None
   H) Don't know

2. Resin can be defined as:
   A) A polymer that not yet been formed into its final useful shape
   B) A plastic that prior to forming exists in a liquid state
   C) The waste created during injection molding
   D) A petroleum based additive used in the manufacture of most plastics
   E) Don't know

3. T / F / D (D=don't know) Many thermosets can be reheated and reformed.

4-6: Match the following types of bonds with their respective definitions:
   A) Covalent
   B) Ionic
   C) Metallic
   D) Don't know

4. _____ This type of chemical bond forms when electrons are transferred from one atom to another so that one bears a positive and the other a negative charge.

5. _____ This type of chemical bond forms when two atoms that tend to give up electrons come close together and both give up electrons forming a loosely held sea of shared electrons.

6. _____ This type of chemical bond forms when two atoms that tend to gain electrons come close together and share electrons.

7. Carbon atoms have ____ valence electrons.
   A) 2
   B) 4
   C) 5
   D) 6

8. Long polymer chains are formed by the building up of the chain from smaller units called _______.

A) Atoms
B) Molecules
C) Monomers
D) Elastomers

9. For polymerization to occur the basic unit of the polymer chain must either contain a carbon-carbon double bond, or active sites that can react with other basic units. Condensation polymerization occurs when:

A) there exists a carbon double bond
B) there exists reactive sites on the basic unit
C) Neither
D) I don't know

11. Melt Strength can be defined as the

A) The property of a polymer that reflects the ability of some liquids to respond to tensile forces.
B) The maximum tensile strength exhibited by a polymer before transitioning from solid to liquid phase.
C) A measurement of how resistant a plastic is to heat
D) A measurement of the heat needed to melt a polymer
E) I don't know

12. As the molecular weight of a polymer increases, the melt index for that polymer ______.

A) Increases
B) Decreases
C) Stays the same
D) Molecular weight is unrelated to the Melt Index
E) I don't know

13. Degree of polymerization refers to:

A) The temperature at which the polymerization reaction takes place
B) The number of repeat units in the polymer chain
C) The level of crosslinked polymer in a plastic
D) I don't know

14. In general a plastic with a broad molecular weight distribution will have

A) Good impact toughness
B) Poor impact toughness
C) Molecular weight distribution has no effect on impact toughness
D) I don't know

15. In general a plastic material which is highly crosslinked will be

A) Tougher than if it had no crosslinking
B) More brittle than if it had no crosslinking
C) I don't know

16. The glass transition temperature is the temperature at which __________.

A) The polymer chains can move freely past one another.
B) A plastic becomes leathery and pliable
C) A monomer begins to react with adjacent molecules
D) I don't know

17. A material with high viscosity is ______.

A) Runny
B) Thick
C) I don't know

18. When some plastics are bent or stretched there often appears an area where the plastic becomes discolored or cloudy. This is referred to as blushing. If the plastic is subject to repeated stretching or bending in this area it will eventually break. At a molecular level what is taking place?

A) The action of stretching or bending causes amorphous areas of concentration in the material which increases brittleness.
B) The stretching and bending of the molecules in these areas causes oxidation degredation to occur.
C) The stretching and bending causes alignment of molecules within the material that causes crystalline regions to form. These regions cause brittleness.
D) I don't know

19. The Izod Charpy test is used to measure:

A) Hardness
B) Tensile Strength
C) Sheer Strength
D) Impact Strength
E) I don't know

20. T / F / D Clay, ground limestone, and sawdust are common fillers in plastic materials.

21. Two samples of the same resin are pulled in tension at two different rates. One at 1 inch per minute and the other at 10 inches per minute. Which would you expect to elongate the most before failure?

A) The 1 inch per minute sample
B) The 10 inch per minute sample
C) I don't know

Manufacturing Automation Pre-test

1. Which would be the most practical choice of actuators to automate the raising and lowering of a hospital bed?
   a. electric
   b. hydraulic
   c. pneumatic
   d. I don't know

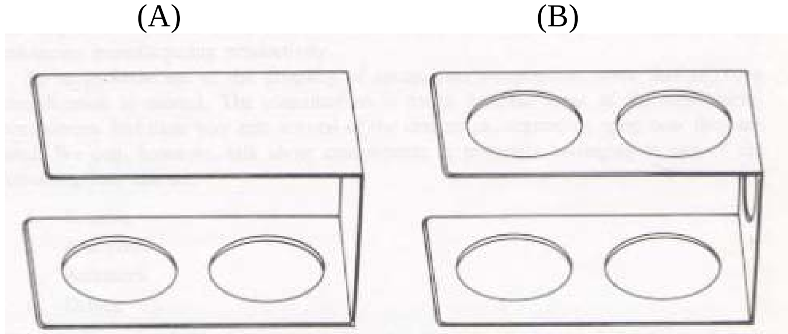
2. Generally, which type of cylinder actuation system can supply the greatest force in the smallest space?
   a. pneumatic
   b. hydraulic
   c. I don't know

3. How great is the force exerted on a 3-inch diameter hydraulic cylinder when 2600 psi oil is allowed to act on it?
   a. 2,600 lbs.
   b. 18,380 lbs.
   c. 24,500 lbs.
   d. 7,800 lbs.
   e. I don't know

4. It is often necessary to improve the quality level of parts being handled by automation in order to:
   a. Improve the quality of the product.
   b. raise the price of the product to pay for the automation.
   c. make the automation task economically practical.
   d. It is not often necessary to improve the quality of the parts.
   e. I don't know.

5. Consider the two part designs below. Which design would appear to be more appropriate for automation? Or does it matter? (Explain or circle one.)

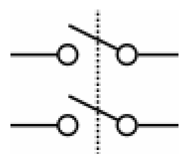
(A) (B)



6. The first bar code below reads —609—. By using this information and comparing the two lines of code, what does the second line read? (Hint: each character consists of five bars.)

a. 906
b. 996
c. 006
d. 699
e. I don't know

7. The following schematic represents a _______ switch.



a. Single-pole, double-throw
b. Single-pole, single-throw
c. Double-pole, double-throw
d. Double-pole, single-throw
e. I don't know

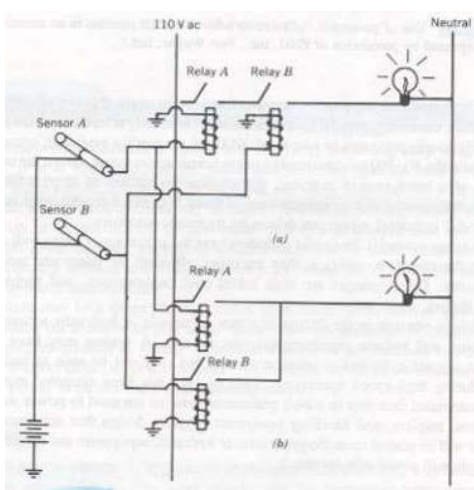
8. Convert the base-10 number "11" to base-2.

___ ___ ___ ___

9. An absolute optical encoder has 4 rings on its optical disk. The bit pattern output reads 1001. What is the absolute angular position of the shaft? (round to the nearest whole number)

a. 180
b. 45
c. 101
d. 203
e. I don't know

10. In the schematic shown at right which sensor(s) must supply a signal in order to light the top bulb?



a. Sensor A
b. Sensor B
c. Both Sensors A and B
d. I don't know

11. Suppose a bar code has 101 feasible characters but only 21 are valid. If a reader error occurs, what would be the approximate chance that a wrong character will be substituted?

a. 10%
b. 20%
c. 30%
d. 40%
e. 50%
f. I don't know

12. The driver of a Geneva mechanism is used to index an assembly-machine table. During normal operation the driver:

a. rotates intermittently.
b. makes two complete revolutions between consecutive stations on the table.
c. can be adjusted for different numbers of revolutions between consecutive stations on the table.
d. rotates continuously.
e. I don't know.

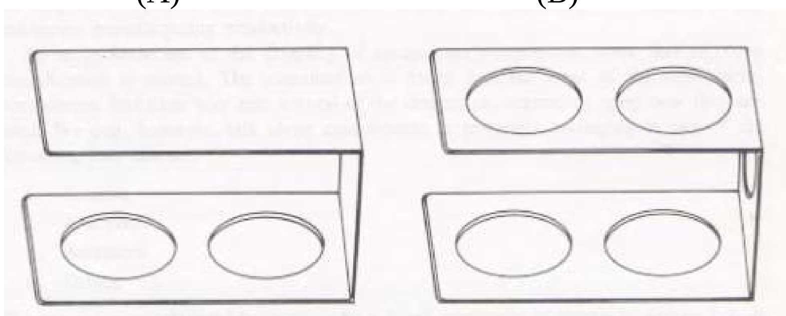
13. A 100% effective vibratory parts selector system has an efficiency of 33.3%. What is the average number of kickbacks per part for this system?

a. 1.00
b. 1.25
c. .50
d. 2.00
e. I don't know

Manufacturing Automation Post-test

10. Consider the two part designs below. Which design would appear to be more appropriate for automation? Or does it matter? (Explain or circle one.)

(A) (B)

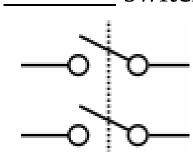


11. T / F Part symmetry complicates automation.

12. The first bar code below reads —609—. By using this information and comparing the two lines of code, what does the second line read? (Hint: each character consists of five bars.)

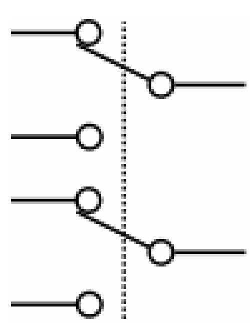
a. 906
b. 996
c. 006
d. 699
e. I don't know

13. The following schematic represents a _______ switch.



a. Single-poll, double-throw
b. Double-poll
c. Double-poll, double-throw
d. Double-poll, single-throw
e. I don't know

14. The following schematic represents a _______ switch



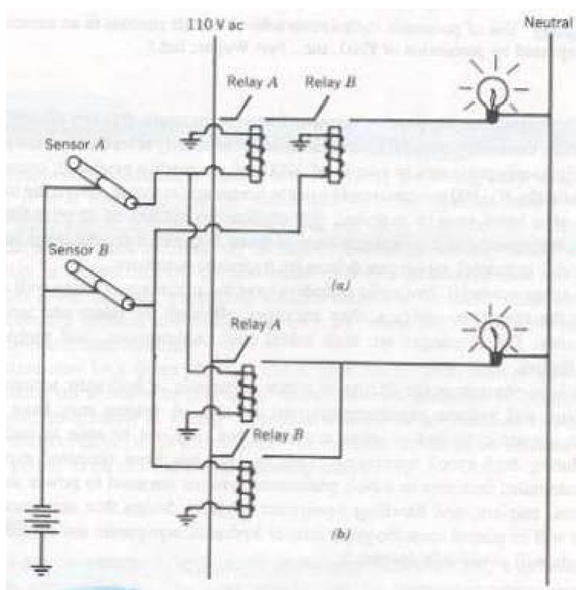
a. Single-pull, double-throw
b. Double-pull

c. Double-pull, double-throw
d. Double-pull, single-throw
e. I don't know

15. An absolute optical encoder has 4 rings on its optical disk. The bit pattern output reads 1001. What is the absolute angular position of the shaft? (round to the nearest whole number)
    a. 180
    b. 45
    c. 101
    d. 203
    e. I don't know

16. Generally, which type of cylinder actuation system can supply the greatest force?
    a. pneumatic
    b. hydraulic
    c. I don't know

17. In the schematic below which sensor(s) must supply voltage in order to light the top bulb?
    a. Sensor A
    b. Sensor B
    c. Both Sensors A and B
    d. I don't know



18. Suppose a label code has 101 feasible character configurations but there are only 21 valid characters recognized by the code. If a reader error occurs, what would be the approximate chance that a wrong character will be substituted?

   a. 10%
   b. 20%
   c. 30%
   d. 40%
   e. 50%
   f. I don't know

19. A 100% effective vibratory parts selector system has an efficiency of 33.3%. What is the average number of kickbacks per part for this system?

   a. 1.00
   b. 1.25
   c. 1.50
   d. 2.00
   e. I don't know