DETERMINING THE INSTRUCTIONAL LABORATORY FACILITY REQUIREMENTS CRITICAL FOR INCLUDING ENGINEERING DESIGN IN THE TECHNOLOGY EDUCATION PROGRAM

By

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(Under the Direction of Robert C. Wicklein)

ABSTRACT

Engineering design as a focus for technology education is beginning to find its way into the technology education curriculum (Dearing & Daugherty, 2004; Hailey, Erekson, Becker, & Thomas, 2005; International Technology Education Association [ITEA], 2000; Wicklein, Smith, & Kim, 2008). This focus is designed to help students achieve technological literacy as well as provide opportunities for incorporating cross-disciplinary standards-based instruction. In order to create an environment conducive for teaching engineering design focused curriculum, new facility requirements must develop. With this new facility design, technology education instructors will have the ability to apply rigorous curriculum components that assist students in developing the mental processes necessary for problem solving. These problem solving skills will enhance the students' ability to attain high-skill, high-demand, and high-wage careers. This Delphi study solicited expert opinion to determine the instructional facility requirements critical to teach engineering design content within high school technology education environments. Panel members emerged from five critical areas that had vested interests in engineering design focused technology education programs. One set of panel members were university professors specializing in teaching engineering design concepts to future technology education teachers. A second area consisted of university professors specializing in teaching engineering to future engineers. A third area consisted of individuals specializing in the construction of school facilities. A fourth area of participants consisted of expert technology education high school teachers identified by the International Technology Education Association (ITEA). A fifth group of participants came from career and technical education (CTE) administrators. The study was conducted via the Internet and participants completed and submitted all survey instruments electronically. It is important to note that each of the participants completing all rounds in this Delphi research process brought expert knowledge from a variety of fields. Participants were able to utilize their professional familiarity with implementing, teaching, supervising, curriculum development, and designing and constructing of technology education programs.

INDEX WORDS: Engineering Design, Environmental Pyscolology, Laboratory Instruction, School Architecture Design and Development, Technology Education, Technology Education Facility Design,

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"Between saying and doing many pair of shoes is worn out" ~ Italian Proverb.

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CHAPTER 1

INTRODUCTION

Technology Education, Engineering and Technology, Technology and Engineering, Pre-Engineering, Industrial Arts, Industrial Technology Education and STEM Education are some old, new, and existing names the field of technology education uses to describe themselves to the general populous. Professionals around the nation spend time agonizing over names that best describe, promote, and give new and fresh meaning to technology education programs. One unintended consequence is the confusion this creates among teachers, administrators, and the public. Often times the names become blended together and tend to become interchangeable to those outside the profession because of a lack of understanding about the intended deference between the old and new program names. For this study engineering and technology education, engineering design, and engineering design focused technology education are names used to convey the reality that technology education is evolving to include engineering design concepts in many states and regions throughout the United States.

This evolution is not a new phenomenon. In fact, since the late 1800s, technology education has continually evolved. It has transitioned through methodological and philosophical modifications to meet the demands of an ever-changing technological society, and has kept pace with industrial innovation and growth. During the 1960s, secondary industrial arts curricula focused mostly on woodworking, metalworking, and drafting (Dugger et al., 1980). While there was value in this content, leaders in the field during this period, like Paul DeVore, Edward Towers, and Donald Maley, proposed different views about the content base for industrial arts.

With the creation of various curricular documents (Industrial Arts Curriculum Project [IACP], Maryland Plan, American Industrial Project), many industrial arts educators in the 1980s became perplexed with the different curriculum plans and ideas (Lewis & Zuga, 2005). Wright (1992) suggested that because the focus and direction of the field was so fragmented, many teachers reverted to teaching traditional content (woodworking, metalworking, drafting), using the same methods they had always used.

The leaders of the era sought a compromise to the curriculum dilemma. Industrial arts supervisors from West Virginia created an opportunity to bring curriculum specialist of the time together to synthesize their ideas into a comprehensive curriculum plan (Lewis & Zuga, 2005). This plan evolved into *The Jackson's Mill Curriculum Theory* (Snyder & Hales, 1981) which focused on the scope and role of technology in the modern industrial workforce (Lewis & Zuga, 2005).

Dr. Robert Wicklein of the University of Georgia considers the beginning of the modern era of technology education to begin with the publication of *The Jackson's Mill Curriculum Theory* document (Wicklein, 2006). Perhaps history will place Wicklein's *Five Good Reasons for Engineering Design as the Focus for Technology Education* (Wicklein, 2006) as the publication that marked the beginning of a new era in technology education; an era in which engineering design content was a primary focus for curriculum. Perhaps it is an era in which technology education will gain greater value and understanding, higher levels of academic achievement, a solid curriculum framework, a platform for integrating mathematics and science, and multiple career options for students who complete coursework within the technology education program.

Hill (2006) stated that engineering design "can provide a focus for the field of technology education that is applicable for students in all grade levels and career pathways" (p. 46). A definition of Engineering Design can be found in the curriculum guide-lines of the Accreditation Board for Engineering and Technology (ABET) it reads:

> Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. The engineering design component of a curriculum must include most of the following features: development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statements and specifications, consideration of alternative solution, feasibility considerations, production processes, concurrent engineering design, and detailed system description (Eide, Jenison, Mashaw, & Northup, 2002, pp. 79-80).

Given this definition, Hill contended that an engineering design focused technology education curriculum provides hands-on design and problem-solving activities enabling students to "express aesthetic and artistic creativity" (Hill, 2006, p. 46). Engineering design as a focus for technology education enables practitioners in the field to give students instruction that accounts for interests, and individual differences, including thinking styles, because of its inherent ability to develop creativity in students (Lewis, 2005).

During the 1990s, and early 2000s secondary-based technology education focused on promoting technological literacy for all students. Students learned that technology is used to create the human-made world. With instructional activities that incorporated technological literacy concepts many state departments of education and local school systems called for major laboratory and facilities redesigns (Georgia Department of Education, 2001). The redesign needed specific lab requirements (instructional/auxiliary spaces with minimum square foot requirements), updated equipment list, computers and computer software, and many lab enhancements i.e. furnishings, floor coverings, audio visual equipment, and safety and security requirements. Many school systems had little criteria to follow when designing new or existing technology education facilities that met changing curriculum focus other than commercial equipment suppliers.

Today, there is a growing body of literature supporting engineering as a focus and direction for technology education (Asunda & Hill, 2007; Dearing & Daugherty, 2004; Garmire, 2003; Gattie & Wicklein, 2007; Lewis, 2004, 2005; Scarcella, 2005; Wicklein, 2006). Historically, Calvin Woodard's manual training movement of the late 1800s was based on the Russian system of technical training for engineering students in the use of tools, materials, and processes (Smith, 1981). Based on these early practices Bensen and Bensen (1993) described a scenario where industrial arts at the time of the Smith-Hughes Act would have indentified itself with the engineering profession, "the big three of industrial arts: woods, metals, and technical drawing would have given way to the big three of engineering e. g., civil, mechanical, and electrical" (p. 3). Foster (2005), identified engineering systems as the fourth highest rated curriculum approach for technology education. These findings supported the claims of Bensen and Bensen (1993). Believing engineering instruction was a more appropriate focus for the curriculum as we entered a new century, they said, "it is imperative that we engage the engineering profession" (Bensen & Bensen, 1993,p. 5).

Though research tends to support the inclusion of engineering content in the technology curriculum, little is known about how to go about it. Gattie and Wicklein (2007) conducted a national study of high school teachers of technology education where they identified teachers with a very positive view of the value of engineering design as a focus. An average of 90.6% of the survey respondents indicated agreement or strong agreement with the fourteen statements on the benefits of including engineering design in the technology education curriculum. In the same survey the respondents agreed on the need for additional assistance in developing an appropriate curriculum, showing disconnect between acceptance and application.

Even with the lack of assistance in curriculum development, it is evident from an examination of the literature that engineering related instruction has earned inclusion in many state curriculum redesign projects (Lewis, 2004). States like Georgia have developed engineering and technology performance standards that reflect and address national concerns about students' low performance in mathematics and science subjects (Georgia Department of Education, 2007). These standards are the first step in developing course curriculum that will help students become technologically literate citizens.

Curricula linked to the Standards for Technological Literacy (ITEA, 2000), Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1993), and National Science Education Standards (National Research Council, National Academy of Sciences [NRC NAS], 1996), have the potential to transform current national practices in technology education to include engineering design. These practices should include the use of mathematics, science, and engineering in real world applications. Wicklein (2006) suggested that by organizing the technology education high school curriculum around the study of engineering design, educators will be able to accomplish the goal of technological literacy, and at the same time create a well defined and respected framework of a study that is understood and appreciated by all.

Leaders in the field believe that focusing technology education curriculum with engineering design content will provide a method of incorporating cross-disciplinary standards-based instruction while meeting the goal of technological literacy (Hailey, Erekson, Becker, & Thomas, 2005). An engineering design focus will require updating and enhancing much of the technology laboratory, equipment, tools, and materials traditionally used by technology education teachers. New teaching procedures are beginning to find an audience, and existing curriculum is being modified by the inclusion of engineering design into the curriculum. Further study, research, and experimentation should bring to light needed changes in the laboratory to meet the needs of students (Advisory Committee on Engineering and Technology Education in Georgia, 2008; Childress & Rhodes, 2007; Gattie & Wicklein, 2007). This study will solicit the expertise of educators knowledgeable about engineering and secondary education to determine necessary laboratory and facility requirements for teaching related curriculum content to high school students.

Purpose of Study

This Delphi study set out to determine the instructional facility requirements critical to teach engineering design content in high school environments. Given the lack of research available for decision makers regarding equipment and facilities needed to teach engineering design focused curriculum, and engineering design as a focus for technology education is a new concept with a limited research base, the Delphi method was selected as the research method for its effective means of facilitating a group decision process on a complex subject or problem (Linstone & Murray, 1975). To determine the essential features of these facilities, a coordinated group provided informed feedback about the requirements necessary for developing this type of learning environment. This study developed consensus among the selected group of experts. The results will inform practitioners about the necessary steps to adequately equip high school laboratories for teaching engineering content.

Research Questions

1. What are the laboratory/facility requirements- in terms of various instructional spaces and their size (square footage) - necessary for teaching engineering design focused technology education at the high school level?
2. How should high school technology education laboratories be configured for teaching engineering design concepts?
3. How should high school technology education laboratories be equipped for teaching engineering design concepts?

Environmental Psychology on Facility, Architecture, and Design

The literature relating to how children learn is critical to those who design engineering focused technology education programs. Too often, the practical applications of learning theory are overlooked for when writing standards, creating curriculum, or designing facilities through which to deliver content. Taba (1962) identifies three general theories of learning: faculty psychology, behaviorism, and Gestalt theory. Those who subscribe to the theory of faculty psychology believe the mind contains all the necessary faculties, and the purpose of education is simply to bring these out with learning exercises.

Behaviorist theory suggests the mind contains a collection of responses, which manifest when triggered by specific stimuli. Behaviorists believe learning takes place by associating responses with their stimuli. This conditioning may be encouraged with positive or negative reinforcement. Gestalt and related field theories believe that the human mind is an organizer of previous experience and cognition. All perception is recorded in memory, creating a cognitive structure. New perceptions are processed relative to this cognitive structure; that is, learning is an active process of selecting from and reorganizing this cognitive map. The goal of this selecting/reorganizing is to create a new insight; an intellectual gain that comes about by using prior experience.

Elements of each of these general theories of learning have filtered into the technology education curricula. Faculty psychology, the theory that best supports the notion of studying difficult subjects, tends to have the least relevance. Behaviorism is observed in many activities traditionally used for teaching technology education. Curriculum based on behaviorist principles are highly structured as they attempt to associate specific responses with set stimuli. The emphasis is on memorization. Specific content, rather than general principles or ideas, are at the center of the curriculum. The job analysis method of curriculum development (Bobbit, 1924; Charter, 1923), historically used by vocational programs, incorporates many of the principles of behaviorism.

The Gestalt theory encumbers the problem solving and systems approaches which are accepted instructional methods for delivering engineering focused technology education curriculum. Programs that are designed with these approaches in mind provide greater emphasis on general principles and creative intuition than in the past (Sanders, 1990).

Learning theorist such as Pavlov, Thorndike, Guthrie, Hull, and Skinner (Bolles, 1975) have studied the aspects of why learning happens. They have developed varied definitions of learning in which one commonality holds true between definitions. The common aspect is change (Brown, 1990). Across disciplines of psychology and education, theorists have composed definitions that encompassed various aspects and amounts of experience, behavior, reinforcement, practice, and environment (Brown, 1990). Yoakham and Simpson (Snelbecker, 1985) provided a definition that is appropriate to engineering focused technology education instructional environments:

> Learning is active. Learning is a function of the total situations surrounding the child. Learning is guided by purpose and consists of living and doing, in having experiences and seeking to understand the meaning of them. (p. 13)

This idea of the school's curriculum, program learning theories, and teaching methods must be present when developing new facilities. These factors balance, and enhance the school environment. In fact, environmental planning must be a prerequisite to the planning of a facility. Facility planning includes safety considerations, the determination of equipment and furniture, lighting and color specifications, size of areas, door and window specifications, marker and bulletin board peripherals, audiovisual equipment, computer and computer related equipment, and a variety of other aspects that are architecturally specific (Brown, 1990). To properly plan for new facilities one must consider environmental planning to establish the philosophical guidelines for the facility by studying the impacts educational facilities have on student achievement.

There is growing evidence of correlation between the adequacy of school facilities and student behavior and performance. Studies conducted over the past three decades have found significant statistical relationships between the condition of a school, or labs and classrooms within the school, on student achievement (Bowers & Burkett, 1987; Schneider, 2002; Tanner & Lackney, 2006). Generally, students attending school in newer, better equipped and technologically up to date facilities score five to seventeen points higher on standardized tests than those attending in substandard buildings (Cash, 1993).

Industrial research from the 1920s has established the relationship between environmental factors and employee productivity and morale, but these lessons have not been widely applied to educational settings (Bowers & Burkett, 1987). In recent years, however, the importance of school facilities has become increasingly better recognized. There are now eight states where the courts have explicitly made the funding of capital facilities a part of education equalization remedies (National Clearinghouse for Educational Facilities [NCEF], 2002).

School facility factors such as building age and condition, quality of maintenance, temperature, lighting, noise, color and air quality can affect student health, safety, sense of self and psychological state. Research has also shown that the quality of facilities influences citizen perceptions of schools. They can serve as a point of community pride and increased support for public education (Tanner & Lackney, 2006).

Poorly designed and maintained school buildings contribute to lost class time. It is universally agreed that the most important classroom variable is time (Carnegie Foundation for the Advancement of Teaching, 1988). Research has established a relationship between time and learning (Carnegie Foundation for the Advancement of Teaching, 1988). Every school year, many hours of precious and irreplaceable classroom time is lost due to lack of air conditioning, broken boilers, ventilation breakdowns, and other facilities-related problems. In addition, computers, printers, networks, and equipment breakdowns contribute to lost class time (Earthman, 1998).

Widely accepted characteristics from the literature about successful schools include the following: a high level of family and community involvement; an emphasis on basic skills; effective leadership; high expectations on the part of teachers and students; high levels of collaboration and communication; frequent monitoring of teaching and learning; focused professional development; and a supportive, safe, orderly, civil, and healthy learning environment (Carnegie Foundation for the Advancement of Teaching, 1988; Earthman, 1998; Tanner & Lackney, 2006).

Most education research is focused on social factors. The perception is that social factors have more of an influence on teaching and learning than physical factors (Tanner & Lackney, 2006). The result is that physical factors are largely ignored when dealing with poor quality teaching and poor student achievement. Researchers may be overlooking the obvious. It is becoming more and more apparent that the learning environment itself has a positive or negative effect on education outcomes (Earthman & Lemasters, 1998).

The socio-economic status of students is the most important external factor in learning, and cannot be controlled. Time in learning is the most direct internal factor that can be controlled (Carnegie Foundation for the Advancement of Teaching, 1988). Because the physical environment has an important influence on time in learning, and other indirect, but significant, factors in the learning process, policymakers are starting to consider a building-based change process for school improvement (Cash, 1993).

Earthman (1998) suggested that the influence of the physical built environment is often subtle, sustained, and quite difficult to measure with precision. He explains that we all know from personal experience that settings do make a difference. Most people concede that their inner feelings upon entering a cathedral are different from the feelings they experience entering a cafeteria or a parking garage. Commercial, retail, and entertainment industries spend large amounts of money to create desirable spaces that set mood and ambiance for their patrons. Earthman (2000), suggested that individuals associate various feelings with their settings.

Building, settings, and environments symbolize certain qualities, values, aspirations, and experiences for individuals. A school or room within the school may symbolize opportunity, hope, stability, or safety in an otherwise harsh world. In contrast, a student may perceive his school environment as a symbol of failure and oppressive authority. The physical environment can have a direct impact on human health and well being (Tanner & Lackney, 2006).

Practitioners in the field of school design and construction believe that the health and safety of people within the school building should be a top priority (Earthman, Cash, & Berkum, 1996). They commonly believe that students should attend school in a safe physical environment (Earthman et al., 1996). According to their research, the most important safety related elements within a school building should be: potable water; fire safety; adequate lavatories; security systems; and a communication system to use in emergencies (Earthman et al., 1996). Addressing such safety issues is considered the highest priority.

Earthman (2004) indicates the following criteria, in the order listed, have a demonstrable impact on student:

1. Human Comfort—i.e., temperatures within the human comfort range as regulated by appropriate HVAC systems.
2. Indoor Air Quality—i.e., appropriate ventilation and filtering systems, also as regulated by appropriate HVAC systems.
3. Lighting
4. Acoustical Control
5. Secondary Science Laboratories
6. Student Capacity—Elementary
7. Student Capacity—Secondary

The number one priority is human comfort. There is extensive research demonstrating a strong correlation between a comfortable temperature range, air-conditioning, ventilation, and heating systems and student achievement. Earthman noted the installation of a good central air-condition system in a school building would also eliminate indoor air quality problems. Illnesses caused by a poor environment result in student absences that also result in lower performance on such measures as achievement tests.

In addition, poorly ventilated buildings can result in poor air quality and build-up of noxious odors and fumes. These fumes can result in student listlessness and absence from school, which results in poor academic achievement (Earthman, 2004). According to research by Schneider (2002), improper lighting in the classrooms can cause poor performance by students while in school, as well as negative effects on eye sight for the rest of a student's life. An additional element to consider during facility planning would be adequate control of the acoustical environment. Numerous studies have shown a positive correlation between appropriate acoustical conditions and student achievement.

A major priority is the improvement of secondary school science laboratories. Studies show that students in schools with appropriate modern science facilities, in both elementary and secondary schools, perform better than students in schools without such facilities (Earthman, 1998). Engineering is considered a science in that it integrates the sciences with areas of traditional engineering such as research, design and analysis (Georgia Department of Education [GADOE], 2008). States such as Georgia have begun to give science credit for students who have taken upper level engineering and technology courses, thus providing a strong argument for improving engineering focused technology education facilities.

Lastly, there are several studies that demonstrate the effects of overcrowding in both elementary and secondary school environments (Earthman, 1998). Evidence affirms small schools general improve education by creating small, intimate learning communities where students are well-know and can be encouraged by adults who care for them (Schneider, 2002).

Significance of the Study

Leaders in the field of technology education believe that including engineering design content will provide a method of incorporating cross-disciplinary, standards-based instruction while meeting the goal of technological literacy (Hailey et al., 2005). In fact, many states, including Georgia, have re-written their mission for technology education to include engineering design as a focus (GADOE, 2007). In a recent study, McVearry (2003) reported that technology education teachers favor the inclusion of engineering design in the technology education curriculum.

Wicklein (2006) points out that the inclusion of engineering design is favorable because;

> engineering is more understood and valued than technology education by the general populace, engineering design elevates the field of technology education to higher academic technological levels, engineering design provides a solid framework to design and organize curriculum, engineering design provides an ideal platform for integrating mathematics, science, and technology, engineering provides a focused curriculum that can lead to multiple career pathways for students. (p. 26)

Though the literature tends to support the inclusion of engineering design content as a focus for technology education, there are many challenges in need of attention before there can be successful implementation. One such challenge professionals continue to identify is the “inadequate or inappropriate laboratory configurations” (Gattie & Wicklein, 2007, p. 9). In addition, in a recent Georgia Engineering and Technology Education Advisory Committee report, Georgia's teachers ranked facilities as the third most important issue related to the implementation of engineering design as a focus for technology education (Advisory Committee on Engineering and Technology Education in Georgia, 2008).

School facility design is a complex process that involves a host of variables, and contributions of many individuals from a variety of fields. In order to develop a practical and useful facility, from the beginning, all interested parties must join the process. This will help develop consensus about the direction technology education will take in laboratory facilities design. Although the process is complicated, time consuming, and dependent on a great deal of evaluation, a starting point is the understanding of the basic principles related to curriculum focused on engineering design.

When planning technology education facilities that incorporate engineering design content, one must identify the concepts that will remain relatively stable through time. Though technology education has and will continue to change, there is a need to develop a solid foundation upon which to base decisions for facility, and equipment. Without this foundation, facilities will fall short, leaving educators unable to deliver meaningful instruction to their students.

To develop desired facilities and provide a solid framework in which to work, curriculum must include engineering design concepts and related academic connection. As with any curriculum development process, there is a need to identify the purpose of the curriculum, the resources, and the societal needs, and then to outline the instructional content that will meet these needs (DeVore, 1991). Without the curriculum design firmly in place, teachers and administrators have little to help guide them in ordering new equipment or remodeling or updating existing facilities. This practice runs the risk of spending difficult to obtain money in a wasteful manner. Facilities must incorporate designs to meet curriculum needs. Before equipment, software, textbooks, etc., are purchased, they must first meet the criteria for enhancing and supporting the stated curriculum of the program.

The National Center for Engineering and Technology Education (NCETE) was recently established to "infuse engineering design, problem solving, and analytical skills into K-12 schools through technology education (Hailey et al., 2005, p. 23). The main focus of NCETE is to prepare educators to introduce engineering design concepts to high school-aged students, as well as outline research topics for the field of technology education (Hailey et al., 2005).

As a result of the guidance NCETE has provided, researchers have conducted studies in hopes of establishing engineering concepts necessary for teaching students in grades 9-12 engineering design, problem solving and analytical skills. Delphi studies by Dearing and Daugherty (2004), Childress and Rhodes (2007), and Smith (2006), with a subsequent article by Wicklein, Smith, and Kim (2008), have provided a basis in which to frame a curriculum. The overriding goal of this research was to establish consensus among a select group of experts for the essential and most critical engineering concepts necessary for infusion in high school technology education programs.

This growing body of research has established that an engineering design focused curriculum helps students achieve technological literacy (Dearing & Daugherty, 2004; Hailey et al., 2005; ITEA, 2000; Wicklein, 2006). As schools continue to implement an engineering design focus into new or existing technology education programs, it has been difficult for teachers and administrators to determine what they may need to develop a high quality technology education program (Advisory Committee on Engineering and Technology Education in Georgia, 2008).

Often, schools must make major decisions related to laboratory facilities, equipment needs, textbooks, and computer hardware and software with little time and information to guide them (Advisory Committee on Engineering and Technology Education in Georgia, 2008). Facility design is a major process that requires an expert in the field of engineering and technology education. School personnel that have little or no knowledge of the scope, concept, or philosophy behind engineering focused curriculum often conduct this planning (Georgia Department of Education, 2001). If research-based support materials develop, facilities will be capable of supporting an engineering and technology curriculum based on national and state standards (Advisory Committee on Engineering and Technology Education in Georgia, 2008).

In addition, commercial vendors are vigorously attempting to establish their products as viable solutions for incorporating engineering content into the technology education curriculum. These commercial vendors are more than willing to aid teachers and administrators as they plan and implement an engineering focused technology education facility. One obvious limitation of vendor driven curriculum and equipment, is that vendors often times skew their recommendations to include their line of equipment and curriculum, which may not be the best fit for the teacher or school (LaPorte & Sanders, 1993). In order to successfully implement engineering design content into the technology education curriculum, teachers and administrators need reliable information regarding facilities, and equipment that is not vendor driven (Georgia Department of Education, 2001).

In order for teachers and administrators to have an opportunity to make informed decisions about how best to implement engineering design focused curriculum in terms of facilities and equipment, specific guidelines must develop (Advisory Committee on Engineering and Technology Education in Georgia, 2008). This study will provide research based information for aiding schools as they make decisions regarding the implementation of facilities that support engineering design focused curriculum. Teachers and administrators will be able to refer to the study to help them with the design, size, and configuration of their facilities, safety consideration, tool selection, major equipment purchases, computer hardware and software needs. An additional result of the study will be that administration and teachers will be able to determine what type of budget will be necessary for school systems to allocate for the purpose of implementing an engineering focused technology education curriculum.

Limitations of the Study

Accuracy of a Delphi study is based on the knowledge of its participants. Therefore, the selection of appropriate participants is the most important step in the entire process because it directly relates to the quality of the results generated (Judd, 1972; Taylor & Judd, 1989). Since the Delphi technique focuses on eliciting expert opinions, Delphi subjects are selected based on areas of expertise required by the specific issue. Kaplan (1971) states that in fact, there is no exact method of selecting Delphi participants. Often times Delphi subjects are considered eligible to participate if they have somewhat related backgrounds and experiences concerning the desired issue.

Helmer and Rescher (1959), Klee (1972), and Oh (1974) concur that choosing individuals who are simply knowledgeable concerning the target issue is not sufficient or recommended. Considering the necessity of selecting the most qualified individuals, only subjects that are highly trained and competent within the related target issue through a nomination process of well-known and respected individuals will be selected (Ludwid, 1994).

This is a critical issue, and it will be important to make every effort to insure each participant has the necessary knowledge and skills, and level of expertise to make this study meaningful. Otherwise, the data collected could be skewed, inaccurate, and basically meaningless.

This study does not take into account the philosophical differences that may exist within the field of technology education. Professionals from the field of technology education seem to be split about how to best apply engineering design concepts. The questions are: is it engineering design focused curriculum for general education purposes for all students, or is it engineering design focused curriculum for pre-engineering education that focuses on preparing students for careers in engineering. Many experts from the field of technology education continue to debate the advantage and disadvantages of both. I explore this in greater detail in chapter 2 but in general this study is closely aligned with engineering design concepts as general education for all students.

Summary

Engineering design as a focus for technology education is beginning to find its way into the curriculum (Dearing & Daugherty, 2004; Hailey et al., 2005; ITEA, 2000; Wicklein, 2006). This focus is designed to help students achieve technological literacy. In order to create an environment conducive for teaching engineering design focused curriculum, new facility requirements must develop. With this new facility design, technology education instructors will have the ability to apply rigorous curriculum components that assist students in developing the mental process necessary for problem solving. These problem solving skills will enhance the students' ability to attain high-skill, high-demand, and high-wage careers.

CHAPTER 2

REVIEW OF THE LITERATURE

History

A review of the literature suggests that engineering instruction has long been a part of the history of what was once called manual training, industrial art, and now technology education. Foster (2005) contended "we have long included the processes of engineering in our program" (p. 19). An early example of including engineering was the Russian, or tool-instruction era advocated by Victor Della-Vos, in which industrial arts leaders advocated the use of engineering functions (Foster, 2005).

Since that time, many historical movements have developed to advance the field towards a unified curriculum that reflects societal needs. These advances include William Warner's (1947) *Curriculum to Reflect Technology,* Edward Towers, Donald Lux, and Willis Ray's *Industrial Arts Curriculum Project* of the 1960's, Donald Maley's *Maryland Plan* of the 1970s, and James Snyder and James Hales *Jackson's Mill Industrial Arts Curriculum Theory* of the 1980s, which brought about the renaming of industrial arts to technology education.

Charles Richards proposed the term industrial arts in 1904, in an editorial while he served as an editor of the *Manual Training Magazine* (Smith, 1981). In this editorial, Richards introduced more than the name, industrial arts; he implied that the content of the instruction was to be influenced directly by industry. Educators like Russell and Bonser, who were most influential with interpreting and applying Richards' ideas, credit him with inspiring them.

As early as 1909, Dean James Russell of Columbia University published in *The School and Industrial Life*, where he suggested elementary education include economic, humanistic and scientific studies in the general curriculum. Russell defined economic as "the study of industries for the sake of a better perspective on man's achievement in controlling the production, distribution, and consumption of the things which constitute his natural wealth" (as cited in Smith, 1981 p. 187). Russell believed that industrial arts should replace fine arts, domestic art, and domestic science in the elementary education curriculum (Smith, 1981).

Bonser's ideas were very similar to Russell's. In fact, Bonser and Mossman (1923) defined industrial arts as "those occupations by which changes are made in the forms of materials to increase their values for human usage. As a subject for educative purposes, industrial arts is a study of the changes made by man in the forms of materials to increase their values and of the problems of life related to these changes" (p.5). The definition centers on material changes and the societal implication of those changes. The emphasis on life problems maintains the direction of relating instruction to real events and the aspects of life, the meaning and methods of application, and shows the students how the instruction is relevant to their lives (Foster, 1994).

Many call Bonser the founder of industrial arts. Unfortunately, his work was cut short with his untimely death while working at the Teachers College at Columbia University (Bartow, Foster, & Kirkwood, 1994). This left other pioneering industrial arts educators like Russell, Mossman, and Erikson the task of developing applications and best practices for teachers to implement meaningful instruction to students in their classrooms.

Mossman (1929) added new aspects to Bosner's description of industrial arts, to better define the intent. She refined Bosner's definition to include the following: procuring and producing raw materials, manufacturing these raw materials, and distributing these materials and commodities to the people who consume them. Mossman set up the first general shop, in which students earned experience in shop work, drawing, and home economics (Foster, 1995). William E. Warner revolutionized industrial arts with his interpretation of Mossman's general shop in his *A Curriculum to Reflect Technology* (1947). He later would give credit to Bonser, leaving Mossman's place in history uncertain (Foster, 1995).

In 1948, Gordon Wilber published *Industrial Arts in General Education*, in which he defined industrial arts as "those phases of general education which deal with industry, its organization, materials, occupations, processes, and products, and with the problems of life resulting from the industrial and technological nature of society" (p. 2). Bosner and Mossman's industrial arts definition is similar to Wilber's except that Wilber substitutes the concept of industry with technology (Foster, 1994). Some considered Wilber's publication to be the basic text for professional courses in industrial arts teacher education.

In 1973, Donald Maley published *The Maryland Plan* in which industrial arts, as a curriculum area, is defined as "those phases of general education which deal with technology, its evolution, utilization, and significance; with industry, its organization, materials, occupations, processes, and products; and with the problems and benefits resulting from the technological nature of society" (p. 2). This definition is similar to Wilber's except for Maley's inclusion of the passage concerning technology (Foster, 1994).

These major events helped shape industrial arts. The debate about focus and direction, however, continued through the years. As a result, curriculum initiatives began to provide definition to the field. One such initiative, created by William E. Warner, with help from his students at The Ohio State University, was called *A Curriculum to Reflect Technology* (1947). The significance of this work was that it divided the study of industrial arts into five subcategories: communication, construction, power, transportation, and manufacturing. Industrial Arts Education, from the 1950s through the 1970s, was based on one of three areas: industry- as exemplified by the Industrial Arts Curriculum Project and the American Industry Project; technology-as promulgated by Olson and DeVore; and the needs of the child-as found in Maley's work (Wright, 1992).

Industrial arts professionals in the 1980s were divided in thought between all of the different curriculum plans and ideas (Lewis, & Zuga, 2005). Leaders of the era sought a compromise to this curricular dilemma. Curriculum specialists of the time gathered together in West Virginia to synthesize their ideas into a plan that would find common ground between the various curriculum strategies (Lewis & Zuga, 2005). This effort culminated into *The Jackson's Mill Curriculum Theory* (Snyder & Hales, 1981). This theory became a national compromise and ended the period of experimentation in favor of a concerted effort to implement "the study of human endeavors in creating and using tools, techniques, resources, and systems to manage the man-made and natural environment for the purpose of extending potential and the relationship of these to individuals, society, and the civilization process" (Snyder & Hales, 1981, p. 2).

Educators in the American Industrial Arts Association (AIAA) embraced the Jackson's Mill Curriculum Theory as the direction for technology education curriculum in the United States. In 1985, the AIAA adopted a name change to better reflect the focus on the study of technology, becoming the International Technology Education Association (ITEA). ITEA advocated teaching technology in the vein of the Jackson's Mill Curriculum Theory compromise (Lewis & Zuga, 2005).

Ten years after the Jackson's Mill project, Leonard Sterry and Ernest Savage provided an updated document, *A Conceptual Framework for Technology Education* (1991). This document kept many ideas from the Jackson's Mill Curriculum Theory, which defined technology as "a body of knowledge and the systematic application of resources to produce outcomes in response to human needs and wants" (p. 7). The framework described by Sterry and Savage explained the technological method as problem solving and listed content for the field as the technological processes of bio-related, communication, production, and transportation technologies (Lewis & Zuga, 2005).

The field of technology education continued to achieve significant curriculum advancements in the years after the Jackson's Mill Curriculum Theory. One such advancement was the *Technology for All Americans Project*. In this project, William Dugger, in conjunction with ITEA, sought funding from the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) to create a unified, cohesive curriculum focus (Lewis & Zuga, 2005). The result of this effort was perhaps the most important long-term organizational and curriculum project directly related to technology education (Smith, 2006).

The endeavor was large in scope and design, calling for intense collaboration among educators at various levels, as well as content experts. Their efforts have led to several major publications which emphasized the importance of technology literacy for citizens, and it advocates the study of technology for all children. The major publications of this project are: *Technology for All Americans: A Rationale and Structure for the Study of Technology* (ITEA, 1996); *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), and *Advancing Excellence in Technological Literacy: Students Assessment, Professional Development, and Program Standards* (ITEA, 2003). These documents have provided the field of technology education with overall conceptual continuity in promoting technological literacy within schools (Lewis & Zuga, 2005).

The Technology For All Americans (ITEA, 1996) document has three main sections: (1) Need for technological literacy, (2) Universals of technology, and (3) Integrating technology into the curriculum. The goal of this document was to provide a clear and defined curriculum with emphasis on the importance of technological literacy.

Building on the *Technology for All Americans* document, *Standards for Technological Literacy* (ITEA, 2000) developed curriculum standards. The purpose of this document was to provide "a vision of what students should know and be able to do in order to be technologically literate" (p. 7). The vision includes twenty content standards that link to curricular goals for technology education at the K-2, 3-5, 6-8 and 9-12 grade levels (ITEA, 2000). The goals of the standards are to focus curriculum in such a way as to help students achieve technological literacy.

The final document to date based on *The Technology for All Americans* project is the *Advancing Excellence in Technological Literacy: Professional Development, and Program Standards* (ITEA, 2003). This document provided further explanation of how teachers, administrators, and others could participate in the goal of technological literacy for all students (ITEA, 2003).

Engineering Design Concepts

The National Center for Engineering and Technology Education (NCETE) was recently established through funding from the National Science Foundation (NSF) as one of 17 Centers for Learning and Teaching (Hailey et al., 2005). The goal of NCETE is to "infuse engineering design, problem solving, and analytical skills into K-12 schools through technology education, and increase the quality, quantity, and diversity of engineering and technology educators" (Hailey et al., 2005, p. 23). Engineering design is an important aspect of NCETE.

One of the main foci of NCETE is to prepare engineering and technology educators to introduce engineering design concepts to high school aged students. In addition NCETE has identified research topics that include "how and what students learn in technology education (engineering and technological concepts, critical thinking and creative problem solving)" (Hailey et al., 2005, p. 25).

NCETE has identified a need to research what essential engineering-related concepts should be included into the technology education curriculum to attain the ultimate goal of infusing engineering design, problem solving, and analytical skills into K-12 education. Leaders in the field of technology education, as well as leaders in engineering, believe changes in curriculum focus in both fields are in order (Dearing & Daugherty, 2004). Dearing and Daugherty (2004) pointed out that:

> both professions encourage teaching engineering design and related concepts at the secondary level, the challenge lies in identifying core engineering-related concepts that also support a standards-based technology education curriculum and concepts that adequately prepare students for both post-secondary engineering education and technologically literate citizenship. (p. 9)

Dearing and Daugherty (2004) framed their study around the research question, "what are the core concepts of engineering that need to be taught in a standards based secondary level technology education program that is focused on pre-engineering" (p. 9)? They found the top ten engineering-related concepts that should be infused into technology education were:

1. interpersonal skills, including teamwork, group skills, attitude and work ethic
2. the ability to communicate ideas verbally and orally
3. working within constraints

4. ability to brainstorm and generate ideas
5. ability to assess product design
6. ability to troubleshoot technological devices
7. ability to understand mathematical and scientific equations
8. understanding of various engineering fields
9. gain experience developing a portfolio
10. ability to possess basic computing skills

In all, they found sixty-two essential engineering-related concepts. These concepts are aligned with *Standards for Technological Literacy*, *Engineering 2020*, and the *Accreditation Board for Engineering and Technology* (ABET).

Childress and Rhodes (2007) conducted their study in cooperation with NCETE to answer the question, "for grades 9-12, what should be included in a technology education curriculum that infuses engineering design, where the goal of the curriculum is technological literacy" (p. 4)? Answering this question, however, required the prerequisite question, "what are the engineering student outcomes that prospective engineering students in grades 9-12 should know and be able to do prior to entry into post-secondary engineering programs" (p. 5)? They found that 43 of 54 total items achieved consensus, 21 items were rated at 4 median or "more important" to include in the curriculum and one item was rated at a 4.5 median, which conceptually means "most important" (Childress & Rhodes, 2007, p. 14-15). It is important to note that these items were identified with the intent that they were to be taught to high school students who want to pursue engineering as a career focus after they graduate from high school.

Smith, (2006) designed his study around the question “what are the essential aspects and related academic concepts of an engineering design process in secondary technology education curriculum for the purpose of developing technological literacy” (p. 4).

He conducted a four-round Delphi study to gather expert responses to four open-ended research questions related to engineering design in technology education. The four related questions were:

1. What aspects of the engineering design process best equip secondary students to understand, manage, and solve technological problems?
2. What mathematics concepts related to engineering design should secondary students use to understand, manage, and solve technological problems?
3. What specific science principles related to engineering design should secondary students use to understand, manage, and solve technological problems?
4. What specific skills, techniques, and engineering tools related to engineering design should secondary students use to understand, manage, and solve technological problems?

Smith (2006) reported on items found to be “undeniably very important” by only selecting items that showed an inter-round mean of <15%, a median score of 5 or 6, and an IQR of <1 (p.10). A total of 29 items arranged into four areas were reported as essential aspects and related academic concepts of an engineering design process in secondary technology education curriculum.

The three studies were conducted to create a level of consensus for engineering concepts essential for developing a clear and definable curriculum. Similarities between the studies suggest that a curriculum that focuses on the integration of engineering or engineering design would be beneficial to technology education as a whole. Smith (2006) noted that the “creation of a widespread acceptance of such a curriculum framework could help to bring a greater degree of solidarity to a fragmented assortment of approaches to the delivery of technology education courses currently practiced in high schools across the county" (p. 13).

Of the three studies, Smith (2006) focused on more of a broad-based, general education approach for incorporating engineering design concepts into the technology education curriculum. While Dearing and Daugherty (2004), and Childress and Rhodes (2007) incorporated more of a pre-engineering approach for the study of technology education. The focus of their studies incorporated engineering concepts that closely related to preparing students who indented to pursue engineering as a career. Still, one can argue that as a byproduct of a pre-engineering approach both students who wish to become engineers, and students who wish merely to become technologically literate can do so with a curriculum geared for pre-engineering.

The same can be argued for a more general education approach, in which engineering design concepts are incorporated so that all students gain general engineering, technological, interpersonal skills, and as a byproduct become influenced to pursue engineering as a career.

Engineering Design as a Vocational Education Program

Rojewski (2002) pointed out that the purpose of Career and Technical Education is to produce "highly skilled and highly educated workers" (p. 9). David Snedden believed that vocational education is "irreducibly and without unnecessary mystification, education for the pursuit of an occupation" (as cited in Dewey, 1915, p. 34). Influenced by Charles Prosser, and David Snedden, together with a growing need to prepare young people for the world of work, the federal government passed the Smith-Hughes Act of 1917. This act declared "vocational education as a separate and distinct system of education that included separate state boards of vocational education, funding, areas and methods of study, teacher preparation programs and certification, and professional and student organizations" (Rojewski, 2002, p. 14).

Both Prosser and Snedden believed that an essentialist approach to learning was best in vocational education. Prosser was an advocate of public education that prepared its citizens to serve society as well as meet the labor needs of business and industry (Swanson, Wright, & Halfin, 1970). Sarkees-Wircenski and Scott (1995) proposed an essentialism philosophy describing the purpose of career technology education as education that meets the needs of industry; utilizes sequential curriculum, has teachers with extensive business experience, and is separate from academic education. With a growing concern over shortages of highly skilled individuals entering the work force, technology education is positioned to incorporate aspects of engineering education into the curriculum, which focuses on the preparation of students for various careers in engineering (Rogers, 2005). This is in response to the high demand for qualified workers in the field of engineering. The U.S. Department of labor reports that a twenty percent increase in the demand for engineers will occur before the end of the decade (Southern Regional Education Board, 2001). In addition, many engineering jobs go unfilled because of the lack of qualified candidates. The National Society of Professional Engineers reported that student enrollment in engineering programs hit a 17-year low in 1999. These figures are compounded by the high attrition rates reported by engineering colleges around the U. S. Given this evidence one can ascertain there is a high demand for competent, qualified engineers (Southern Regional Education Board, 2001).

With this demand in mind, there has been much discussion about aligning pre-engineering with technology education. The National Research Council (2002) believed technology education with an engineering focus can help secondary students understand the impacts of engineering, which, in turn, develops technological literacy. The National Academy of Engineering has endorsed the *Standards for Technological Literacy*, spawning the opportunity for greater cooperation between technology education and engineering (Wright, 2002). Additionally, it has been demonstrated in the literature that technology education has moved towards the inclusion of the engineering design problem solving method for solving technological problems, thus creating additional rational for aligning the two professions (ITEA, 2000; ITEA 2003; NRC, 2002).

One program that aligns technology education with courses that prepare students who aspire to become engineers is *Project Lead the Way* (PLTW). PLTW is a well known pre-engineering program operating in over 1250 schools in 44 states (McVearry, 2003). Richard Blais developed the PLTW program at Shenendehowa Central School District in the 1980s (Blais & Adelson, 1998).

The Southern Regional Education Board (2001) described *Project Lead the Way* as:

> an organization that works with public schools, the private sector, and higher education to increase the quantity and quality of engineers and engineering technologists by providing high school students with engaging pre-engineering education. Students who complete the PLTW pre-engineering program understand: (a) technology as a problem-solving tool, (b) scientific process, engineering problem solving and the application of technology, (c) how technological systems work with other systems, (d) mathematics knowledge and skills in solving problems, (e) communicate effectively through reading, writing, listening and speaking, (f) be able to work effectively with others. (p. 7)

The central focus of *Project Lead the Way* is pre-engineering education that focuses on preparing students for careers in engineering and engineering technology (Rogers, 2005). The Technology

Education Division (TED) of the Association for Career and Technical Education (ACTE) advocates this philosophy, as does the K-12 division of the American Society of Engineering Educators (ASEE). The increased attention in pre-kindergarten through 12^{th} grade (P-12) engineering education is in response to the lack of talent, as well as depth of knowledge necessary for the twenty-first century workforce in the areas related to Science Technology Engineering and Mathematics (STEM) (Harris & Rogers, 2008).

Engineering Design as a General Education Program

Classical education infused with constructivist activities started the American pedagogy entitled Progressive Education (Cremin, 1961). The progressive education movement began as part of a vast humanitarian effort to “apply the promise of American life the ideal of government by, of, and for the people” (Cremin, 1961, p. vii). Progressive education was an effort to use schools to improve the lives of individuals; which meant several things to progressives. First, it meant that the curriculum would include teachings in health, vocation, and the quality of family and community life. Second, it meant that the classroom pedagogical principles would adhere to new scientific research in psychology and the social sciences. Third, it meant that schools would have to change instruction to meet the different classes of children looking for an education. Last, it meant that everyone could share in the benefits of the new sciences combined with the pursuit of the arts as well (Cremin, 1961).

Liberal arts were based on Greek concepts of the “moral and free man;” in which an educated man was “a man who could think clearly, speak effectively, read analytically, and have knowledge of the work and human nature, and know the ways in which the universe operated” (Mason, 1972, p. 25). Core disciplines included rhetoric, logic, grammar, music, arithmetic, geometry, and astronomy. Originally, liberal arts education was for only the wealthy elite.

Historical events like the Industrial Revolution and development of a democratic government created a large middle class in need of an education. The commitment to educate all opened the door for masses to receive a liberal arts education. Of course, this led to an expansion in the liberal arts content to include history, more natural sciences, and the social sciences. Even with the expanded content, the purpose of this type of education did not change (Wiens, 1987). Griswold (1962) wrote the role of liberal arts was "not to teach business men business, or grammarians grammar, or college students Greek and Latin, It is to awaken and develop the intellectual and spiritual power in the individual before he enters upon his chosen career, so that he may bring to that career the greatest possible assets of intelligence, resourcefulness, judgment, and character" (p. 13).

The terms liberal education, liberal arts education, and general education are often used interchangeably (Wiens, 1987). Simply put, the goal of liberal arts or general education is to liberate the student from ignorance and prejudice (Wiens, 1987). Bloom (1987) stated the purpose of liberal education is to "feed the student's love of truth and passion to live a good life" (p. 345). Kranzberg (1991) stated "the purpose of an education [liberal arts and education in general] is not only to train students for a career, but also to challenge them to think about the meaning and purpose of life, their role in both the cosmic and human scheme of things, and their relationship toward their immediate neighbors and toward the larger global society" (p. 238). Cremin (1961) described one of the first examples of liberal education practices in the United States when in the late 1800s, Calvin Woodward developed the Manual Training School. These progressive ideas included a liberal arts education for all students. The main focus of Woodward's school was to divide mental and manual labor equally. Mathematics, drawing, science, languages, history, and literature combined with instruction in carpentry, wood turning, patternmaking, iron chipping and filing, forge work, brazing and soldering, and bench and machine work in metals. The goal of the various courses was liberal rather than vocational; the emphasis was on education, not production for sale.

From these early educational ideas and practices, leading manual arts educators with liberal educational goals refocused the profession and developed a refined subject called industrial arts.

An evolutionary chart of technology education arguably could start with manual training in its various forms, move to industrial arts, and then continue to technology education. During the manual training era the Smith-Hughes Act passed. This forced manual training advocates to decide between holding on to liberal education ideals or "go after Smith-Hughes money" (Lewis, 1996, p. 9). From this dichotomy, two separate camps emerged; vocational and liberal. These camps developed two versions of what was essentially the same content. With this historical perspective one can see that technology education has its roots in both liberal/general, and vocational education philosophy and practices. Zuga (1995) stated that "the confluence of professionals who practiced both vocational education and general education forms of manual training created an ideological paradox for a subject matter purported by its practitioners to have liberal education goals" (p. 3). The result of this early paradox continues to mean technology education is misidentified and misunderstood as a valuable general education subject.

DeVore (1968) recommended that the study of technology be organized by the adaptive technological systems of production, communication, and transportation. Lewis and Zuga (2005) describe DeVore as "an advocate of studying the relationship of society to technology, how we humans create technologies, and how these technologies influence our environment" (p. 11). DeVore advocated "creating a sustainable environment as one of the premier reasons for studying about technology" (as cited in Lewis & Zuga, 2005, p. 11). These early beliefs and practices firmly root technology education as a liberal/general education program for all students.

Early curriculum developments inspired many professionals to develop curriculum innovation, experimentation, and professional discourse in the field of technology education that included provisions for studying engineering (Cochran, 1970). For instance, Towers, Lux, and Ray (1966) developed the Industrial Arts Curriculum Project; Maley (1973) produced the Maryland Plan; and DeVore (1980) refined his conceptualization for the study of technology. The production of new curriculum plans lasted until the 1980s, “when confusion from all the curriculum plans” caused leaders in the field to come together to “synthesize their ideas” in one plan (Lewis & Zuga, 2005, p.10). This plan was call the *Jackson’s Mill Curriculum Theory*. The curriculum developed focused on the adaptive technological systems of manufacturing, construction, transportation, and communication.

Snyder and Hales (1981) described industrial arts, “as a discipline of schooling” (p. 6). This continues to provide evidence and support for a general education curriculum goal. In addition, Snyder and Hales (1981) define industrial arts as a “body of knowledge that contributes to technological literacy, and enhances human potential” (p. 6). These factors created a rallying point for professionals that focused on the teaching of technology, launching the modern era of technology education (Wicklein, 2006).

After the Jackson’s Mill Curriculum Theory, Savage and Sterry (1990) developed, *A Conceptual framework for Technology Education*, in which they noted that incorporating problem solving was the best method for teaching technology. Shortly afterward, the ITEA (1996) developed a curriculum document entitled, *Technology for All Americans: A Rationale and Structure for the Study of Technology*.

This curriculum plan lead to the creation of the, *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), which drew emphasis to medical, agricultural, related bio, energy and power, information and communication, transportation, manufacturing, and construction technologies. The standards included provisions for the nature of technology, relationships of technology and society, design, technological world, and standards regarding understanding the designed world (ITEA, 2000).

These standards are similar to British standards, with which technology education has been incorporated as part of the general education curriculum (Department of Education, 1995). In addition, Kasprzyk concluded that the “disciplines of engineering were, in fact, the content base for technology education (as cited in Bensen & Bensen, 1993, p.4). One can argue that technology education in all its forms has always been intended to be part of the general education curriculum and a progressive, liberal arts education program that broadly focuses on engineering as a main curriculum component within the disciplines of technology education.

One emergent curriculum effort trademarked by the National Center for Technological Literacy (NCTL) at the museum of Science, Boston, is *Engineering the Future: Science, Technology, and the Design Process* (EtF). This curriculum effort is based on the idea that technology and engineering are “two sides of the same coin” (NCTL, 2008, p. xiv). NCTL (2008) describes their curriculum as:

> Curriculum not intended to provide training in specific vocations. It is meant to help all students—whether they eventually choose to attend a university, another tertiary education institution, or enter the world of work—better understand the designed world and the wide variety of career paths a person might take in designing, manufacturing, maintaining, or using technologies. (p. xv)

NCTL (2008) suggests that the course should not stand alone but be one step in a sequence of courses that students take as they progress through high school. The course enables students to have a broader understanding of the wide variety of technical careers open to them. The intent of the course is to inspire students to take more courses in science or math, or more specialized courses in technical fields regardless of whether they intent to become involved in science and technology as careers (NCTL, 2008).

Engineering the Future (EtF) was designed with a backward design process, as described in the book *Understanding by Design* (Wiggins & McTigh, 1998), with 5 main course goals:

1. Students will develop a deep and rich understanding of the term technology.
2. Students will develop their abilities to use the engineering design process.
3. Students will understand the complementary relationships among science, technology and engineering.
4. Students will understand how advances in technology affect human society, and how human society determines which new technologies will be developed.
5. Students will be able to apply fundamental concepts about energy to a wide variety of problems.

Laboratory Instruction - Historical Issues

Technology education has utilized laboratory based instruction to deliver a variety of concepts to students over its 110 year history. Early laboratory configurations mirrored the philosophy and curriculum framework of their era, which enabled teachers to deliver meaningful instruction that met course objectives. John Dewey (1933) claimed that providing hands-on experiences enhanced and complemented student learning. Dewey's belief was that genuine understanding can be achieved through doing. He believed that education should be a series of situations in which students are involved in solving problems of interest to them. This is the basis for the project method where students are engaged in activities that require thinking as well as doing. Dewey suggested students apply the scientific method to solve problems. This method of teaching required laboratory instruction with enough tools and equipment for formulating ideas and solutions for any give problem (Dewey, 1916). Cardon (2000) believed that by incorporating hands-on projects, it added value to student learning. Cardon (2000) also believed that students in technology education classes were better motivated to stay in school because of the positive hands-on experiences provided to them by technology teachers. The unit laboratory, general unit laboratory, comprehensive general laboratory, and technology laboratory were designed to provide the best learning environment for the student, the community, the state, the region, and the nation (Polette, 1995).

William E. Warner wrote that society had changed after World War II from an industrial complex to an elaborate social environment that consisted of producers, consumers, and managers of technology (Warner, 1947). This lead to Warner's general area shop theory in which he argued that the use of a general area shop was more appropriate than the use of the traditional unit shop (Warner, 1947). Warner's vision of the general area shop included tools and machines that could be used for a variety of materials and processes such as wood, metal, drafting, electricity and power, transportation, ceramics, plastics, leather, and graphic arts (Nair, 1959). These shops, or laboratories, were arranged and planned so that one or more teachers could teach in various locations simultaneously (Nair, 1959). This was opposed to the unit shops, where instructional focus was on one material, process, or single undivided area such as cabinetmaking, machine shop, or sheet metal (Nair, 1959). This form of laboratory design was associated with manual training in which students were taught machine shop, print shop and other types of single subject matter (Nair, 1959).

Delmar W. Olson expanded Warner's idea of using technology as the content base of industrial arts in his book, *Industrial Arts and Technology* (Olson, 1963). In this book, Olson expanded the general area shop to include a modular format. This is not to say that Olson intended these labs to be autonomous curriculum units, he envisioned flexibility in instructional laboratories, with students moving between stations and utilizing the tools and materials in an integrated manner (Olson, 1963).

The fundamental change experienced in laboratory design during the technology education era was the notion of being part of the whole school program. This meant that technology education's place in the school building was to teach the hands on applications of the concepts learned in science, mathematics, social studies, and language arts. Dean (1997) believed that a new technology education facility design must develop with a new paradigm. Dean suggested a gender friendly lab where the integration of academics, impacts of technology, application of technology systems, use of technology resources, problem solving using technology, career awareness, multicultural/gender diversity and ethics, could be taught.

The modern day modular laboratory associated with technology education was developed in 1985 by Max Lundquest and Mike Neden (Dean, 1997). This laboratory configuration was developed out of concerns and confusion many professionals experienced when the American Industrial Arts Association (AIAA) changed their name to International Technology Education Association (ITEA) at the 1985 San Diego conference (Dean, 1997). Lundquest and Neden returned to Pittsburg, Kansas to create a middle school laboratory that would reflect their vision of the new technology education paradigm. Numerous states around the nation were quick to adopt their design, down to the smallest details (Dean, 1997).

In addition, many states produced and published facilities planning guides and recommendations based on the Pittsburg Middle School. These guides consisted of rational statements, physical plant designs with sample lab layouts, square footage requirements, classroom enhancement such as LCD projection systems, and equipment lists.

Historically, the modular laboratory concept has its roots in LT. Neville Postlethwait's perspective of programmed instruction. In the 1960s, Postlethwait used programmed instruction to create "a small unit of subject matter which could be treated coherently as an individual topic and could be conveniently integrated into a study program" (Russell, 1974, p. 3). Then, in the early 1970s, the term module emerged as a generic description for individualized learning packages (Bolvin, 1972). Russell (1974) defined a module as an "instructional package dealing with a single conceptual unit of subject matter. It is an attempt to individualize learning by enabling the student to master one unit of content before moving to another (p. 3). Since the 1980s commercially created modular technology education programs have grown in use and application considerably despite research opinions concerning the merit and effectiveness of the modular concept (Brusic & LaPorte, 2000).

Daugherty, Klenke, and Neden, (2008) pointed out that the modular concept has proven successful in teaching technology education explorations in many middle schools around the United States. They continue to explain that "unfortunately, many schools integrated that methodology into all grade levels, making it less effective" (Daugherty et al., 2008, pg. 22).

Laboratory Instruction – Current Issues

Technology education courses that focus on engineering design as a curriculum component are essentially laboratory courses in which students are expected to design, build, and test prototypes (NCTL, 2008). While students can learn a great deal from textbooks and discussion sessions, laboratory experiences are necessary for a greater understanding of what engineering is all about (NCTL, 2008). As with any curriculum development process, there is a need to identify the purpose of the curriculum, the resources, and the societal needs, and then to outline the instructional content that will meet these needs (DeVore, 1991). Without the curriculum design firmly in place, teachers and administrators have nothing to help guide them with the ordering of new equipment or remodeling or updating existing facilities. This practice runs the risk of spending difficult to obtain money in a wasteful manner. Facilities must be designed to meet curriculum needs. Before equipment, software, textbooks, etc, are purchased they must first meet the criteria for enhancing and supporting the stated curriculum of the program (Daugherty et al., 2008).

Daugherty et al. (2008) suggested that "all contemporary technology education facility changes should be based on an alignment with *Standards for Technological Literacy* (SLT)". The goal of standards based laboratory instruction is to provide students with hands-on learning experiences that utilize constructivist learning techniques. Although these standards are key to understanding the essential components of an effective technology education laboratory, there is little research too support such a claim (McCrory, 1987).

Daugherty et al. (2008) write:

> With the advent of Standards for Technological Literacy and current curricular trends, consistency of instructional facilities is a crucial next step in establishing the field both

> politically and socially. In order to standardize technology education, it is necessary to standardize the essential elements within the technology education laboratory. This homogeny not only insures a consistent educational delivery platform across the county, it will help define the profession within the modern school environment. (p. 22)

Daugherty et al. (2008) described the model technology education facility as including four distinct learning environments:

1. The presentation center: designed for instructor-led presentation, multimedia presentations, student presentations, and for the exploration of technological concepts and ideas.
2. The Communication Center: designed to allow for research and development, internet research, and individual and group investigations and activity.
3. The resource/testing center: designed to give space for group engineering design, problem solving, cooperative learning, and other group interactions.
4. The fabrication center: designed for inventing and innovating engineering models, prototypes, and mock-ups.

Daugherty et al. (2008) believed that technology education facilities should "provide space for the introduction, exploration, engagement, and expansion of technological ideas, concepts, and principles" (p. 22).

Burrows (2008) conducted a study to gather information from practicing engineers about the activities, skills, and equipment necessary for teaching engineering and technology at the high school level. He concluded that this type of facility must be separated into three basic areas by percent of overall lab space available.

His conclusion was 29.29% of the overall lab space should be dedicated to lecture and seating, 35.71% to computers and testing equipment, and 35% to prototype development (p.31).

Constructivism Approach to Learning

The educational theory known as constructivism is based on the foundational works of Dewey, Piaget, and Vygotsky (Bransford, Brown, & Cocking, 2000). The basic philosophy is, "people construct new knowledge and understanding based on what they already know and believe" (Bransford et al., 2000, p. 10). Wankat (2002) writes "learning is done by the students, not by the professor, learning is always based on what the students know and believe" (p. 3). Jacobson and Wilensky (2006) suggested that young learners can handle complex systems thinking at all levels of education, stating, "a central tenet of constructivist or constructionist learning approach is that a learner is actively constructing new understanding, rather than passively receiving and absorbing facts" (p. 22).

Building on what people already know is an active process requiring a number of steps (Bransford et al., 2000). Wankat (2002) listed 3 basic steps to build upon what people already know:

> First, students need to be motivated to spend the time and energy necessary to build or rebuild a knowledge structure. Second, students need to learn correct facts. Third, the framework of the knowledge structure needs to be organized in a way that helps the students retrieve and apply the knowledge (p. 4).

Jacobson and Wilensky (2006) believed that this method of teaching is more interesting, engaging, and motivating for students. They contend that students increase their understanding of complex systems by solving authentic problems within a cooperative learning environment.

Wanket (2002) added that to learn efficiently, people must use meta-cognition to control their own learning processes. Meta-cognition requires students to first make sense of what concept is being taught by relating it back to their own knowledge structure. Second, students will need to be able to look inward for self-assessment. They will need to be able to self-assess their learning to know if they understand the material correctly. Last, students must reflect on what they learned, by determining what learning approaches worked during the learning process.

Bradford et al., (2000) contended that the ideal classroom environment for a constructivist approach is a classroom that includes:

Learn centered--pay attention to the students' preconceptions, skills and attitudes;

Knowledge centered--pay attention to the subject, student understanding and mastery;

Assessment centered--use frequent formative assessment by both the teacher and the student to monitor progress;

Community centered--The context of learning is important. Combined argumentation plus cooperation enhances cognitive development (p. 133-149).

Similar ideas have been expressed by Dyer, Reed, and Berry (2006).

They cited Crawford and the Center for Occupation Research and Development who listed five key strategies to actively engaging students in a constructivist approach to teaching in exemplar classrooms. These five strategies are:

Relating--learning in the context of one's life experiences or preexisting knowledge;

Experiencing--learning by doing, or through exploration, discovery, and invention;

Applying--learning by putting the concepts to use;

Cooperating--learning in the content of sharing, responding, and communication with others;

Transferring--using knowledge in a new context or novel situation--one that has not been covered in class (Crawford in Dyer et al., 2006, p. 8).

School Architecture- Design and Development

Teachers of today's schools face increased academic expectations and lack minimum funding. The failing economy has caused state and local education policy makers to cut budgets to bare minimum. Many school systems have to scramble to make up budget shortcomings by cutting money allocated for new equipment, supplies, building maintenance, instituting furlough days, suspending all pay increases, encouraging early retirement, suspending hiring of new staff members causing existing staff to pick up the slack, and some systems have resorted to layoffs.

Despite the uncertainty teachers continue to do more with less. It is not uncommon to visit schools and see students' excelling in creative classrooms. The production of educational video games, constructing and programming robots, and creating web-based portfolios are common among today's students. In fact a growing trend in many schools is the concept of paperless classrooms, where teachers are required to create and maintain class websites where students access all course materials. They then pass all assignments in electronically where the teacher grades and returns electronically to both student and parents. For teachers to stay current with curriculum, educational theory, and classroom technology, greater requirements have been mandated. It is more difficult to attain and maintain certification, and professional development has become more time consuming and rigorous.

Though all school personnel have been held to higher standards with regards to student achievement, one area left out of the equation has been how schools are planned, designed, and built (Tanner, 2000). A review by Henry Barnard (1848) cited in Tanner (2000) found;

> public schools are almost universally badly located, exposed to noise, dust and danger of the highway, unattractive, if not positively repulsive in their external and internal appearance, built at the least possible expense of material and labor, are too small, badly lighted, not properly ventilated, imperfectly warmed, not properly furnished, lacking appropriate apparatus and fixtures, and deficient in outdoor and indoor arrangements (p. 310).

Tanner (2000) contended that Barnrd's assessment of school architecture of the 1850's is still valid today.

Earthman (2004) linked student achievement to the condition of the school building. Buildings that are considered poor are those that lack appropriate HVAC systems, have poor lighting, are old, noisy, lack functional furniture, or have some variation or combination of all of these qualities (Earthman, 2004). Over three decades of research make clear that "students in poor buildings perform less well than student in functional or acceptable buildings" (Earthman, 2004, p. 18). Earthman made this statement with findings from research conducted in four different states and two major cities (Cash, 1993; Earthman, 2000; Hines 1996; Lanham, 1999). Earthman (2004) stated "research findings give ample guidance as to what needs to be done to insure a healthy and productive physical environment for all students to permit them to learn to the limit of their capabilities rather than hinder them in the acquisition of knowledge and skills" (p. 18).

Earthman (2004) synthesized many research studies about school building evaluation and found that most had the same basic approach to investigating the relationship between school building conditions and academic achievement (Cash, 1993; Earthman, 2000; Hines 1996; Lanham, 1999). Each study used some form of building evaluation to determine the condition of the building and was able to classify the buildings from poor to good. They also compared the student achievement test scores with the building conditions. Researchers also used the percentage of students receiving free or reduced lunch to control for socioeconomic status of the student body. Each study found a significant difference in the achievement scores of students in poor buildings and in good buildings (Earthman, 2004).

From Earthman's (2004) evaluation of the research a range of 3 percentile rank scores to 17 percentile rank scores were found. Hines (1996) in a study of large high schools found a 17 point difference on one subtest. Earthman (2004) reported the researchers found differences ranging from 5 to 10 percentile rank scores and these differences were statically significant. These differences in achievement scores show that students perform worse in poor buildings. This is causing many students in poor buildings to fall behind students from schools that have the necessary elements to adequately facilitate educational programs.

Impacts of Temperature

Research indicates a strong correlation between student achievement and temperatures falling within the human comfort zone (Cash, 1993; Earthman, 2000; Hines 1996; Lanham, 1999). Review of the literature by Earthman (2004) found:

1. Significant relationships between a controlled physical environment and student achievement and behavior.
2. A strong relationship between air-conditioning and student performance.
3. Student in non air-conditioned buildings performed 3-12 percentile rank points lower on various measures than student in air-conditioned buildings.

4. Room temperatures of 75 degrees Fahrenheit with 50 percent relative humidity and no air movement cause a definite increase in body temperature and pulse rate and a marked fall in vasomotor tone as measured by the Crampton Index.
5. Excessively high temperatures produce harmful physiological effects.
6. An effective temperature range of 67 to 73 degrees Fahrenheit is desirable.
7. Fifteen percent less physical work is performed at 75 degrees Fahrenheit than at 68 degrees Fahrenheit with 50 percent relative humidity and no air movement; at 86 degrees Fahrenheit with 80 percent humidity, the decrease in work performed was 28 percent as compared to the performed at 68 degrees Fahrenheit. (p. 12)

Impacts of Poor Air Quality

Research indicates a strong correlation between poor air quality and poor student and worker performance (Cash, 1993; Earthman, 2000; Hines 1996; Lanham, 1999). Review of the literature by Earthman (2004) found:

1. The US Environmental Protection Agency estimates that more than 10 million days of schooling are lost each year by students because of asthma attacks.
2. Asthma symptoms were higher in students attending schools with high counts of settled dust on floor and furniture than for students in cleaner buildings.
3. A positive correlation between CO2 concentrations in the classroom and the reported student health symptoms and also the performance of students on academic test.
4. When pollution (carpets) were absent office workers improved typing by 6.5%, math scores by 3.8%, and logical reasoning by 3-4%. (p. 13)

Impacts of Lighting Quality

Studies have shown a positive correlation between appropriate lighting and greater student achievement (Cash, 1993; Earthman, 2000; Hines 1996; Lanham, 1999). Review of the literature by Earthman (2004) found:

1. Good lighting quality and proper foot-candles have been found to be positively related to increases in student achievement and performance.
2. Poor lighting quality perform less well on various measures of student achievement.
3. A recent study of 21,000 students found that those in schools with natural lighting scored 20% higher on achievement tests than students in schools with no natural lighting. (p. 14)

Impacts of Acoustics

Studies have shown a positive correlation between appropriate acoustical conditions and student achievement (Cash, 1993; Earthman, 2000; Hines 1996; Lanham, 1999). Many students suffer in schools that are too noisy for them to properly learn. The ability for students to clearly hear the teacher in a classroom is vital to teaching and learning. Review of the literature by Earthman (2004) found:

1. Third grade students in noisy buildings were .4 years behind in reading and .2 years behind in math of students in noisy buildings. Sixth grade students in noisy buildings were .7 years behind in reading.
2. The noise distraction in classrooms that are at a high level results in low performance year after year by students attending these schools

3. Clear evidence to support high levels of noise, both inside and outside the classroom can seriously hinder students from achieving their potential. (p. 14)

Impacts of Equipment and Furniture

Studies have shown a positive correlation between appropriate, adequate, and up to date equipment and furniture and student achievement (Cash, 1993; Earthman, 2000; Hines 1996; Lanham, 1999). Evidence suggests that students from school buildings equipped with modern, and functional furniture and equipment, in particular science equipment, are able to perform better than students in buildings with less modern equipment and furniture on various achievement measures. Review of the literature by Earthman (2004) found:

1. In those buildings that had old equipment and furniture the students scored 8 percentile rank points below students using newer, functional equipment.
2. In elementary schools students from buildings with modern equipment and furniture showed significant difference between students with old outdated equipment.
3. Students using older science equipment, both elementary and secondary, are disadvantaged in learning about science. (p. 15)

Impacts of Overcrowded School Buildings

Research indicates a strong correlation between over populated schools and poor student performance (Cash, 1993; Earthman, 2000; Hines 1996; Lanham, 1999).

Review of the literature by Earthman (2004) found:

1. The result of overcrowding in schools is lower student achievement on both the elementary and secondary levels

2. Overcrowding also results in lower graduation rates among senior high school students.
3. Long term experience in overcrowded schools negatively impacts the work of teachers as well as impacting student performance. (p. 16)

CHAPTER 3

METHOD

This chapter provides a description of the research design and procedures used to conduct this Delphi study. In addition, this section contains a description of the Delphi research procedure, description of the participants, and discussion of how the data will be analyzed.

Research Design

A Delphi method was the research methodology used in the study. According to Wilhelm (2001), when traditional research methods are not appropriate, there are two options. The first is to wait until scientific knowledge emerges to adequately address the problem. The second is to obtain a panel of experts to try to make relevant intuitive insights that enable informed judgments to systematically emerge. The second option describes the Delphi method.

The original Delphi was developed by workers at the RAND Corporation in the 1950s. It began as a way to collect expert opinion from the point of view of a Soviet strategic planner to produce likely scenarios for attacking, counter attacking and possible follow-up response scenarios for destroying U. S. industrial target systems along with corresponding estimations of the number of atomic bombs required to reduce munitions output by a prescribed amount (Dalkey & Helmer, 1963). After initial application of the Delphi methodology, this procedure was utilized to address research needs in private corporations, think tanks, governmental agencies, education, and academia (Wilhelm, 2001).

Dalkey and Helmer (1963) described the Delphi technique as a procedure to "obtain the most reliable consensus of opinion of a group of experts by a series of intensive questionnaires interspersed with controlled opinion feedback" (p. 458). The structure of the technique allows for a wide variety of knowledgeable participants to join together to attain group consensus.

Professional literature indicates that the Delphi research methodology works in various situations such as program planning, needs assessment, policy determination, and resource utilization (Meyer & Booker, 1990). The Delphi technique can be used "to determine or develop a range of possible program alternative; explore or expose underlying assumption or information leading to different judgment; seek out information which may generate a consensus on the part of the respondent group; correlate informed judgments on a topic spanning a wide range of disciplines, and; to educate the respondent group as to the diverse and interrelated aspects of the topic" (Delbecq, Van de Ven, & Gustafson, 1975, p. 11).

Linstone and Murray (1975) developed a list of environments where a Delphi technique would be best employed. Usually, one or more of the following properties of the Delphi leads to the need for employing the application: (a) the problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis; (b) the individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise; (c) more individuals are needed than can effectively interact in a face-to-face exchange; (d) time and cost make frequent meeting unfeasible; (e) the efficiency of face-to-face meetings can be increased by a supplemental group process; (f) disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured; (g) the heterogeneity of the participants must be preserved to assure validity of the results, i. e., avoidance of domination by quantity or by strength of personality.

This proposed study meets the following conditions for implementing the Delphi technique: (1) the problem does not lend itself to precise analytical techniques but can benefit from subjective judgment on a collective basis; (2) more individuals are needed than can effectively interact in a face-to-face exchange; (3) current and historical data is not accurately known or available; (4) examining the significance of historical events; (5) evaluating possible budget allocations.

Anonymity, iteration, controlled feedback, and statistical aggregation of group response are three main elements necessary for conducting a Delphi procedure (Rowe & Wright, 1999). Anonymity allows individual group members a low pressure, private opportunity to express their opinions and judgments without pressure from dominant group members. This enables individuals to judge each idea on its merit, not on social or group pressures. In addition, conducting a series of anonymous iterations provides an additional layer of comfort to participants, which enables them to change their opinions and judgments without fear of losing their credibility to the group.

Controlled feedback is given to Delphi participants between iterations, in which each member receives the opinions of their anonymous colleagues. Usually, mean, median, standard deviation, and interquartile range values are presented as a simple statistical summary of group response along with a well organized summary of the prior iteration (Dalkey & Helmer, 1963). Providing controlled feedback drastically reduces the amount of noise.

Dalkey (1972) explains that noise is the communication that distorts the data and deals with group or individual interests rather than focusing on the problem. By providing feedback, participants become more involved in solving the problem by offering their opinions insightfully, thus minimizing their tendency to influence the study based on narrow self-interests.

After several rounds of iterations, the group judgment is taken as the statistical average of participants. This practice further reduces the potential of group pressure for conformity. In other words, statistical analysis is able to represent the opinions of each participant. This is important because, "at the end of the exercise there may still be a significant spread in individual opinion" (Dalkey, 1972, p. 21). This means that each participant has no pressure to conform to other participant's responses. Statistical analysis allows for an objective and impartial analysis and summarization of the data collected.

The Delphi method was selected for two reasons. First, it is a particularly good research method for deriving consensus among a group of individuals with expertise on a particular topic where information sought is subjective, and participants are separated by physical distance (Borg, Gall & Gall, 2007; Dalkey & Helmer, 1963; Linstone & Murray, 1975). In fact, since its inception, the Delphi method has been demonstrated as a reliable empirical method for reaching consensus in a number of areas (Cochran, 1983; Linstone & Murray, 1975). Rojewski and Meers (1991) suggested that consensus is determined using the inter-quartile range of each research statement. Interquartile range refers to the middle 50% of responses for each statement, such as the distance between first and third quartiles.

Second, the Delphi technique is also a prescribed methodology for cases when participants come from different professions, since anonymity provides a layer of protection for individual voices (Melpignano & Collins, 2003).

This study used a three round Delphi process to determine the facility requirements for teaching engineering and technology to high school students. Descriptive and ordinal data collection and analysis interpret group suggestions and opinions into a collection of descriptive information for making decisions as to the size, configuration, and equipment needs for teaching engineering design focused technology education in high school environment.

Potential problems with the Delphi procedure are that few studies have been done on the methodological aspects of the procedure and questions have been raised with regards to the reliability of Delphi results given the subjectivity of selecting the right experts. These concerns will be minimized by carefully selecting a group of participants known as panelists. These panelists will be selected based on explicit expertise, reliability, and relevant experience. According to Scheele (1975), a successful mix of respondents on a panel includes stakeholders; those who are, or will be directly affected by the study.

In order to conduct a successful Delphi study, the researcher must systematically deal with many inherent problems. First, the researcher must put biases aside when selecting the expert panel participants, interpreting the returned data, and when structuring the next set of questioners. This can be done by resisting the tendency to force the data to fit the models or methods most familiar to the researcher. Second, the process of selecting panelist must be taken seriously, because the quality of participants directly determines the quality of the study. Third, the Delphi method is vulnerable to misrepresentation and sloppy execution (Meyer & Booker, 1990). Therefore, the researcher must use proper techniques when summarizing and presenting the group responses to ensure common interpretations by: (a) providing accurate statistical data; (b) explore disagreements; (c) encourage communication; (d) motivate participants; and (e) understand the demanding nature of a Delphi (Linstone & Murray, 1975).

Participants

In a Delphi study the selection of appropriate knowledgeable professionals is essential. An expert is considered to be "a person who has background in the subject area and is recognized by his peers or those conducting the study as qualified to answer questions" (Meyers & Booker, 1990, p. 3). Ziglio (1996) suggested that experts should be selected using explicit criteria. These criteria may vary from one application to another, depending on the aims and context within which the Delphi process is carried out. In addition, the process for deciding the number of expert panelist is not a statistical one. Ziglio (1996), and Linstone and Murray (1975), suggested that the size of a panel will vary, and with homogeneous groups of experts good results can be obtained even with small panels of 10-15 individuals. Duboff and Spaeth, (2000) suggested educational research panel members could include curriculum innovators, instructional reformers, critical scholars', creative thinkers, and intellectual rebels.

Friel (2001) stated that multiple stakeholders should be involved when selecting a panel of experts, and small panels can obtain good results (Linstone & Murray, 1975; Ziglio, 1996). Based on this information and research, this study identified a panel of 24 diverse participants. Panel members came from five critical areas that had vested interests in engineering design focused technology education programs.

One set of panel members were university professors specializing in teaching engineering design concepts to future technology education teachers, classified as technology education teacher educators. A second area consisted of university professors specializing in teaching engineering to future engineers, classified as engineering educators. A third area consisted of individuals specializing in the construction of school facilities. A fourth area of participants consisted of expert technology education high school teachers identified by the International Technology

Education Association (ITEA) as exemplary technology education teachers. A fifth group of participants came from career and technical education (CTE) administrators that have specialized knowledge for implementing technology education in the high school curriculum.

In an effort to obtain varied points of views, and to have a geographically diverse panel, participants from around the nation were selected. Potential panel members were identified for all participant sub-groups. Six (6) individuals per sub-group for a total of 30 individuals were identified through contact with Drs. Robert Wicklein, Roger Hill, John Mativo, Jay Rojewski, and Kenneth Tanner, faculty members of the Department of Workforce Education, Leadership and Social Foundation at the University of Georgia, Athens. Once the original 30 participants were indentified they were contacted via email and asked to identify additional experts in their sub-group with similar expertise (see Appendix A). This method of identifying potential participants is called the snowball research method. The goal of these contacts was to yield additional qualified panel members in each sub-group. This yielded 26 additional potential participants swelling the participant group to 56 spread between the various subgroups. After these additional panel members were identified, those that meet the criteria were contacted via email (see Appendix B) and asked to agree to serve on the Delphi research panel.

The criteria that all participants meet were: (1) specialized content expertise; (2) vested interest in the implementation of engineering design into secondary education; and (3) experience with technology education curriculum. Table 3.1 displays the actual number of identified participants for each subgroup, who recommended them, level of commitment, known reasons for lack of commitment, and who completed each Delphi survey for the three rounds by area of expertise.

Table 3.1

Participants Information

Technology Education Teacher Educators (TETE) - Participant Information

Participant	Organization	Referred By	Initial Commitment	R-1	R-2	R-3	Known reason for lack of commitment
TETE-1	University Professor	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TETE-2	University Professor	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TETE-3	University Professor	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TETE-4	University Professor	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TETE-5	University Professor	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TETE-6	University Professor	Referred by TETE-2	Yes	Yes	Yes	Yes	Committed throughout the study
TETE-7	University Professor	Committee Members	Yes	No	No	No	Once received the round one survey -- reported lack of expertise in research area
TETE-8	University Professor	Referred by TETE-2	No Response	No	No	No	No response to email invitation

**Seven out of eight committed to study (6 referred by committee, 1 referred by participants). One committed participant later dropped form study.*

Engineering Educators (EE) - Participant Information

Participant	Organization	Referred By	Initial Commitment	R-1	R-2	R-3	Known reason for lack of commitment
EE-1	University Professor	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
EE-2	University Professor	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
EE-3	University Professor	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the student
EE-4	University Professor	Referred by TETE-4	Yes	Yes	Yes	Yes	Committed throughout the study
EE-5	University Professor	Referred by TETE-5	Yes	Yes	Yes	Yes	committed throughout the study
EE-6	University Professor	Committee Members	Yes	No	No	No	Once received the round one survey - reported lack of expertise in research area
EE-7	University Professor	Committee Members	Yes	No	No	No	Once received the round one survey - reported lack of expertise in research

							area
EE-8	University Professor	Committee Members	No	No	No	No	Reported lack of expertise in research area
EE-9	University Professor	Referred by EE 1	No	No	No	No	Reported lack of time to commit to the study
EE-10	University Professor	Referred by EE 9	No	No	No	No	Reported lack of expertise in research area
EE-11	University Professor	Referred by EE 9	No Response	No	No	No	No response to email invitation
EE-12	University Professor	Referred by EE 9	No Response	No	No	No	No response to email invitation
EE-13	University Professor	Referred by EE 5	No Response	No	No	No	No response to email invitation
EE-14	University Professor	Referred by EE 3	No Response	No	No	No	No response to email invitation
EE-15	University Professor	Referred by EE 3	No Response	No	No	No	No response to email invitation

**Seven out of fifteen committed to study (5 referred by committee, 2 referred by participants). Two committed participant later dropped form study.*

Technology Education Supervisors (TES) - Participant Information

Participant	Organization	Referred By	Initial Commitment	R-1	R-2	R-3	Known reason for lack of commitment
TES-1	State Technology Education Supervisors	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TES-2	State Technology Education Supervisors	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TES-3	State Technology Education Supervisors	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TES-4	State Technology Education Supervisors	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
TES-5	State Technology Education Supervisors	Referred by TES-1	Yes	No	No	No	Once received the round one survey – did not complete survey or return email as to reason why
TES-6	State Technology Education Supervisors	Referred by TES-1	Yes	No	No	No	Once received the round one survey – did not complete survey or return email as to

							reason why
TES-7	State Technology Education Supervisors	Committee Members	Yes	No	No	No	Once received the round one survey – did not complete survey or return email as to reason why
TES-8	State Technology Education Supervisors	Committee Members	No Response	No	No	No	No response to email invitation
TES-9	State Technology Education Supervisors	Referred by TES 1	Bad Contact Information	No	No	No	No valid contact information could be found
TES-10	State Technology Education Supervisors	Referred by STET 4	No Response	No	No	No	No response to email invitation
TES-11	State Technology Education Supervisors	Referred by TES 1	No Response	No	No	No	No response to email invitation
TES-12	State Technology Education Supervisors	Referred by TES 1	No Response	No	No	No	No response to email invitation

**Seven out of twelve committed to study (5 referred by committee, 2 referred by participants). Three committed participant later dropped form study.*

Secondary Technology Education Teachers (STET) - Participant Information

Participant	Organization	Referred By	Initial Commitment	R-1	R-2	R-3	Known reason for lack of commitment
STET-1	High School Education	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
STET-2	High School Education	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
STET-3	High School Education	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the student
STET-4	High School Education	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
STET-5	High School Education	Referred by TES-1	Yes	Yes	Yes	Yes	Committed throughout the study
STET-6	High School Education	Referred by TES-1	Yes	Yes	Yes	Yes	Committed throughout the study
STET-7	High School Education	Committee Members	No Response	No	No	No	No response to email invitation
STET-8	High School Education	Committee Members	No Response	No	No	No	No response to email invitation
STET-9	High School Education	Referred by STET 1	No Response	No	No	No	No response to email invitation

**Seven out of nine committed to study (4 referred by committee, 2 referred by participants). No committed participant later dropped form study.*

Facility and Construction (FC) - Participant Information

Participant	Organization	Referred By	Initial Commitment	R-1	R-2	R-3	Known reason for lack of commitment
FC-1	Architecture and Design	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
FC-2	Architecture and Design	Committee Members	Yes	Yes	Yes	Yes	Committed throughout the study
FC-3	Architecture and Design	Committee Members	Yes	Yes	No	No	Finished initial survey did not finish addition surveys – no response to follow-up emails as to why.
FC-4	Architecture and Design	Committee Members	Yes	No	No	No	Once received the round one survey - reported lack of expertise in research area
FC-5	Architecture and Design	Committee Members	Yes	No	No	No	Once received the round one survey - reported lack of expertise in research area
FC-6	Architecture and Design	Committee Members	No	No	No	No	Reported lack of expertise in research area
FC-7	Architecture and Design	Referred by FC 4	No Response	No	No	No	No response to email invitation
FC-8	Architecture and Design	Referred by FC 4	No Response	No	No	No	No response to email invitation
FC-9	Architecture and Design	Referred by FC 1	Bad Contact Information	No	No	No	No valid contact information could be found
FC-10	Architecture and Design	Referred by FC 1	No Response	No	No	No	No response to email invitation
FC-11	Architecture and Design	Referred by FC 2	No Response	No	No	No	No response to email invitation
FC-12	Architecture and Design	Referred by FC 2	No Response	No	No	No	No response to email invitation

**Five out of twelve committed to study (5 referred by committee, 0 referred by participants). Two committed participant later dropped from initial round, one participant dropped after first round survey.*

In total 56 participants were indentified, 30 initial participants from committee members, and 26 additional participants that were identified by the initial participant group as possible candidates for this research study. Of the 56 identified participants, 20 did not respond in any way to the invitation to join the study, and 4 responded they were not interested in participating in the study. This left 32 committed participants 25 that were identified from committee members, and 7 that were identified from other participants. Of the 32, only 24 completed the Round 1 survey instrument 19 participants from the initial participant group and 5 from the participant group identified from the snowball research method. Of the 8 that were sent the Round 1 survey but did not complete, 5 stated after seeing the actually survey, they felt they did not have expertise to participate in the study and felt they should be dropped from the reach group and 3 did not report back in any way as to a reason for dropping form the study.

Instrumentation-Delphi Procedure

Each round in the Delphi process was built on the responses and synthesized results of the previous round. The process stopped when consensus was established, or sufficient information was obtained by the researcher (Delbecq et al., 1975). Consensus is decided when certain percentages of responses fall within a given range (Miller, 2006). Ulschak (1983) remarked that consensus is achieved when 80 percent of responses fall within two categories on a seven-point scale. Other research suggests that at least 70 percent of Delphi subjects need to rate three or higher on a four point Likert-type scale, with a median of 3.25 or higher (Meyer & Booker, 1990). According to Scheibe, Skutch, and Schofer (1975), percent measurements are inadequate and suggest that a more reliable alternative is to measure the stability of subjects' responses in successive iterations.

Analysis of data in Delphi research can involve both qualitative and quantitative techniques (Meyer & Booker, 1990). In the classical Delphi design, researchers deal with qualitative data in the first round of questioning because of the open-ended questions used to solicit participants' opinions about the research problem. In subsequent rounds, quantitative methods identify the level of desired consensus as well as any changes of judgment among panelists. This is usually achieved by calculating measures of central tendency, such as mean, median, mode, and levels of dispersion such as standard deviation, and inter-quartile range, to present information concerning the collective judgments of respondents (Hasson, Keeney, & McKenna, 2000). Mean, median, and mode are favored in Delphi studies that utilize participant responses that are delineated at equal intervals (Murray & Jarman, 1987).

In Delphi literature, the use of Likert-type scales to determine the median of participant response is strongly favored (Hill & Fowles, 1975; Jacobs, 1996). Jacobs suggested, "considering the anticipated consensus of opinion and the skewed expectation of responses as they were compiled, the median would inherently appear best suited to reflect the resultant convergence of opinion" (p. 57). In addition, Delphi researchers find mode useful when reporting data in Delphi research. Ludwig (1994) states "the Delphi process has a tendency to create convergence, and though this was usually to a single point, there was the possibility of polarization or clustering of the results around two or more points, in these instances, the mean or median could be misleading" (p. 57).

Research Plan

An outline for the Delphi process deployed in this study is as follows. First, selected panel members received the subject matter in a structured manner that enabled them to provide evaluated feedback on the topics. Second, a questionnaire was distributed to solicit the opinions of the experts; this was to develop points of convergence or divergence (see Appendix C). Third, questionnaires were distributed again after responses were synthesized from the previous round.

Feedback provided participants with the group's responses as well as their own. This enabled panel members to reconsider their response so group consensus could be reached.

Rounds of Questionnaires

The purpose of the first round of the Delphi process was to determine the initial positions of panelist about the issues involved with the needs of engineering design focused technology education facilities. A series of 15 probe questions (see Appendix C) that were specifically linked to 1 of the 3 research question were asked to all panel members. These probe questions were based on program support materials from Connecticut, Georgia, Massachusetts, North Carolina, and Tennessee. Within each program support material were specific details relating to constructing and equipping technology education facilities. The probe questions were taken from the sample plans, equipment lists and special features provided within the various support materials, put in question form and then presented to the panel members for response. Table 3.2 shows how each probe question connects to the research questions.

Table 3.2

Links between probe questions and research questions

Research Question	Links to Probe Questions
1. What are the laboratory/facility requirements- in terms of various instructional spaces and their size (square footage) - necessary for teaching engineering design focused technology education at the high school level?	Probe Questions (1,2, 9, 13, 14, 15)
2. How should high school technology education laboratories be configured for teaching engineering design concepts?	Probe Question (3, 4, 5, 9, 11, 13, 14, 15)
3. How should high school technology education laboratories be equipped for teaching engineering design concepts?	Probe Question (5,6,7,8,9,10,11,12,13,14,15)

The panel then identified problems, objectives, and solutions to the questions presented to them. From this data, the researcher determined which questions the panel agreed upon, which questions were unimportant, and which questions could be discarded. More importantly, the researcher determined which questions were causing disagreement among the respondents (Linstone & Murray, 1975). The focus for the study was established in this phase with the data the panel generated from their expert knowledge.

In the second round, an additional questionnaire was developed by the researcher based on the panel responses and summarized research results of the proceeding questionnaire. In this round, the panel had the opportunity to reevaluate their original responses given the feedback from the other panel members.

In the third round, the researcher focused on how the expert panel viewed the separate arguments used to defend the various positions, and how each panel member's opinion varied from one to another. At this point, the researcher reevaluated the responses from the panel members to determine relevance of each position taken by the participants.

After all rounds were analyzed, a final report was completed by the researcher. This report summarized the goals and the processes, as well as the results. Anonymity was maintained with regard to individual panelist's inputs identified in the final report.
Areas of agreements and disagreements were presented in detailed explanations. The objective of the report was to help participants understand other panel members' positions.

Procedure for Completing Study

After a list of potential participants was established, the researcher solicited the service of Survey Monkey™. This is a website that enables users to create an account for contacting participants, sending reminder emails, and conduct surveys. This works particularly well when using the Delphi technique because of the multiple rounds of surveys necessary (Wong, 2003). This service posts the information to a web-site where participants will log on at their convenience. The web-site allowed participants to view each question and respond using multiple methods; such as written messages or numerical responses. The researcher dictated how long the participants had to complete the survey by utilizing various functions the service provides. One particularly useful function was the email function; this function enabled the researcher to send emails to participants with regards to the amount of time available for each round of survey.

Study Time Line

During the spring semester of 2009 I contacted the potential participants through email to solicit participation in the study. Though it was not necessary, telephone calls and US mail could have been utilized to make every effort to contact participants. The initial email (See Appendix A) described the study and contained a link to the website. At this point participants accessed the web-site and were prompted to complete simple demographic data and consent to participation in the three-round Delphi study. The number of participants solicited for the study was 24. Twenty-four participants allowed for a natural attrition rate that normally occurs during any study (Martino, 1983). Table 3.1 contains the timeline of the study.

Table 3.3

Study Timeline

Round	Date
Commitment deadline	April, 2009
Round 1	June, 2009
Round 2	July, 2009
Round 3	August, 2009

By the April deadline, all participants indicated their commitment to the study. Prior to the deadline, I sent email reminders for a final effort to attain as many participants as possible.

Round 1

Just after the deadline to join the study passed, I sent an additional email out to those that had agreed to take part in this Delphi study. The email contained instructions for completion of the survey, as well as a hyperlink to the website. Participants answered questions that enabled a review of the data to establish a valid list of all unique responses to the research questions. The data from this round was compiled into unique responses and organized for Round 2.

Round 2

After Round 1 data was reviewed, analyzed and summary data compiled, a Round 2 survey was produced. Shortly after the survey was produced, an email was sent out to each of the participants that completed Round 1. Each unique response identified from Round 1 was included in the Round 2 survey. The participants were able to indicate their level of agreement or disagreement based on a 6 point Likert scale. Participants added any additional items that they wished to add to the list of responses from Round 1. A reminder was sent to all participants who did not complete the Round 2 survey. Where necessary, telephone calls were made to those who did not responded to the email reminder.

Round 2 analyses provided empirical measures of the level of support given by each individual response in the group. Descriptive statistics, and the mean, maximum, minimum, standard deviation and interquartile range were calculated. According to Dalkey (1968), in a Delphi study, the median response is the most important statistic because it most accurately describes the overall rating of the particular item. The mean, standard deviation and interquartile range are used to report on group response to the various items generated by the participants. The interquartile range is a common statistical measure denoting the distance between the 75 and 25 percentiles. The interquartile range is the middle 50% of the responses to an individual item and will be the primary measure of the degree of consensus achieved. A common measure of the interquartile range that indicates an acceptable level of agreement has been identified as less than 1.2 (Custer, Scarcella, & Stewart, 1999). From the detailed data analysis of Round 2, I constructed the questionnaire for Round 3.

Round 3

Round 3 data was analyzed using the descriptive statistics mentioned previously. The purpose of Round 3 was to allow the experts to see how others in the sample group responded in Round 2. In addition, participants were given a chance to revise their own responses in light of the group response to the same items. Thus, the ultimate purpose in Round 3 was to allow the experts to revise their responses to match the other participants.

The researcher provided a space for participants to add comments on any response they felt they needed to explain. A review of the literature finds that in most cases, participants reach their final conclusions by the third round (Cyphert & Grant, 1971; Martino, 1983). Linstone and Murray (1975) contented that three rounds were typically enough for the study to reach stability. The degree of stability in this study will be determined by the percent of mean change between rounds for each response.

Data Analysis for Delphi Procedure

The ultimate goal of a Delphi study is to achieve a level of group consensus about the issues being studied. To identify the amount of agreement or disagree, the median of each Likert scale response is normally calculated (Dalkey & Helmer, 1968). Stonefish and Busby (1996) suggested the most common method used to measure dispersion in Delphi studies is inter-quartile range (IQR) results. These calculations indicate the level of group consensus, or how much the participants agree with one another about each research item. In order to calculate IQR one must first calculate the median of a particular Likert scale response to divide the data into two equal sets of responses. The median is calculated by sorting the data in ascending order. The median is the number in the middle, e. g. the median is equal to the middle value of a set of data. This gives the researcher the ability to calculate the lower and upper quartiles. The lower quartile is the value of the middle of the first set of data, where 25 percent of the values are smaller than *Q1* and 75 percent are larger. The first quartile takes the notation *Q1*. The upper quartile is the value of the middle of the second set of data where 75 percent of the values are smaller than *Q3* and 25 percent are larger. This third quartile takes the notation of *Q3*.

The inter-quartile range measures the spread between the lower and upper quartiles. This distance indicates the dispersion of the data set. The inter-quartile range spans 50 percent of a data set, and eliminates the influence of outliers because, in effect, the highest and lowest quarters are removed. Specifically, the inter-quartile range (IRQ) is equal to the difference between upper quartile (*Q3*) and lower quartile (*Q1*).

Round 3 data was analyzed in the same summative manner as the previous rounds. Collected numerical data was described with statistical summaries through the use of SPSS statistical analysis software. As with earlier rounds, a measure of the level of support given by each individual response in the group was established. In addition, responses lying outside the predetermined range of consensus were identified. At this point the researcher begins the process of generating the final report. Where necessary, the researcher contacted panelists for clarifications on outlying responses they may have had. These contacts aided in data syntheses, for the final report. Delbecq et al. (1975) stated, “particular care should be taken to ensure clarity in preparation of this final statement of results so that individuals who did not participate in the Deplhi study understand the summary categories and phrasing” (p. 105).

CHAPTER 4

RESULTS

A three-round Delphi research process elicited the responses of experts from 5 areas of laboratory facility expertise to three open-ended research questions related to engineering and technology education facilities design. The 5 areas included.

1. University professors specializing in teaching engineering and technology to future teachers.
2. University professors specializing in teaching engineering to future engineers.
3. Individuals specializing in the construction of school facilities.
4. Expert engineering and technology high school teachers.
5. Career technology education administrators.

Completers by Round

In total 56 participants were indentified, 30 initial participants from committee members, and 26 additional participants that were identified by the initial participant group as possible candidates for this research study. Of the 56 identified participants, 20 did not respond in any way to the invitation to join the study, and 4 responded they were not interested in participating in the study. This left 32 committed participants 25 that were identified from committee members, and 7 that were identified from other participants. Of the 32, only 24 completed the Round 1 survey instrument 19 participants from the initial participant group and 5 from the participant group identified from the snowball research method. Table 4.1 displays the actual number of those completing each Delphi survey for the three rounds by area of expertise.

Table 4.1

Completers by Round

Round	Area Of Expertise	n
1	University professors specializing in teaching engineering and technology to future teachers.	6
1	University professors specializing in teaching engineering to future engineers.	5
1	Individuals specializing in the construction of school facilities.	3
1	Expert engineering and technology high school teachers.	6
1	Career technology education administrators.	4
		N=24

Round	Area Of Expertise	n
2	University professors specializing in teaching engineering and technology to future teachers.	6
2	University professors specializing in teaching engineering to future engineers.	5
2	Individuals specializing in the construction of school facilities.	2
2	Expert engineering and technology high school teachers.	6
2	Career technology education administrators.	4
		N=23

Round	Area Of Expertise	n
3	University professors specializing in teaching engineering and technology to future teachers.	6
3	University professors specializing in teaching engineering to future engineers.	5
3	Individuals specializing in the construction of school facilities.	2
3	Expert engineering and technology high school teachers.	6
3	Career technology education administrators.	4
		N=23

Demographic Data

Every effort was made to obtain varied points of view. This produced a geographically diverse panel of participants from around the nation. Panel members were identified for all participant sub-groups, Table 4.2 displays the demographic data of the participants who completed the Round One survey instrument.

Table 4.2

Demographic Data for Round One Participants: N=24

Gender	Average Years of experience	Highest level of education	Area of expertise	Current employment
Male n=21	20.71	Bachelors n=3	Technology Education n=14	University n=11
Female n=3		Masters n=7	Engineering Education n=5	High School n=6
		Ed Specialist n=3	Architecture n=3	Administration n=4
		PhD n=11	Design n=2	Industry n=3

The study was conducted using the service of SurveyMonkey.com™, an internet-based survey website. Once participants were given access to the surveys, they were able to log on and complete all surveys instruments electronically. Data from previous participants was retained in subsequent rounds even if they did not complete additional surveys because this input is considered important and valid even if the participant does not complete subsequent rounds (Ludlow, 2002).

It is important to note that each of the participants completing all rounds in this Delphi research process brought expert knowledge from a variety of fields. Participants were able to utilize their expertise with implementing, teaching, supervising, curriculum development, and designing and constructing of engineering and technology education facilities. This commonality among participants provides strength and focus for the study in that it is easy to categorize the results and compare them with other studies with similarly homogenous groups.

Round One

The Round 1 survey instrument was available to participants online from April 24 to June 1, 2009. Each participant was contacted via email (see Appendix D) and directed to access the study website in order to record their responses to the 15 probe questions (see Table 4.3) that were used to obtain answers for the original 3 research questions that guided this study. The survey instrument was completed by 24 of the 31 persons who had agreed to participate

Table 4.3

Round One Survey Instrument – Probe Questions with link to Research Question (RQ)

Question Number	Probe Question	Link to Research Question (RQ)
1	What types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?	1
2	What types of support spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor	1
3	How should each instructional space be furnished?	2
4	How should each support space be furnished?	2
5	What types of facility safety materials are necessary to provide a safe environment for all students working in the facility?	2,3
6	What types of personal safety materials are necessary to provide a safe environment for all students working in the facility?	3
7	What types of hand tools are necessary?	3
8	What types of hand held power tools are necessary?	3
9	What types of material processing equipment are necessary?	1, 2, 3
10	What types of computer software are necessary?	2,3
11	What types of audio-visual equipment are necessary?	2,3
12	What types of measuring and testing devices are necessary?	3
13	How many computers (and computer related equipment), are necessary?	1,2,3
14	What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, and any other engineering related equipment (if any)?	1,2,3
15	List any other item you feel is necessary for teaching engineering design concepts to high school students that you were unable to list for another question	1,2,3

A total of 1246 responses (see Appendix E) were received from the 24 participants during Round One.

Results of Round One

In order to establish content validity, this data was sent to Drs. Robert Wicklein (Major Professor), Roger Hill, John Mativo, Jay Rojewski, and Kenneth Tanner, University of Georgia faculty members, so they could review the entire list of responses and help condense the data into a list of unique items. The professional literature regarding the Delphi research process recommends a panel of at least two persons to monitor this process of identifying the items that formed the Round 2 survey instrument (Turoff, 1970). Table 4.4 contains the reviewed list of all unique responses.

Table 4.4

Results of Round One Data Review

Area	Number by Area	Description	Number by Area	Description
Probe Question 1 What Types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?				
1.	Combination Computer/Lecture/Presentation Area—(Various Square Footages)			
	1.1.	(1000 to 1500 Square Foot) Combination Computer, Lecture, Presentation Area.	1.2.	(1800 to 2500 Square Foot) Combination Computer, Lecture, Presentation Area.
2.	One Room Multipurpose Lab			
	2.1.	(1000 to 1200 Square Foot) Multipurpose Room for entire lab		
3.	Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work—(Various Square Footages)			
	3.1.	(250 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.		
	3.2.	(600 to 800 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.		
	3.3.	(1000 to 1200 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.		
	3.4.	(1800 to 2000 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.		
	3.5.	(2400 to 2600 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.		

4. Prototyping/Material Processing—(Various Square Footages)
    - 4.1 (120 Square Foot) Prototyping/Material Processing Area.
    - 4.2. (500 to 800 Square Foot) Prototyping/Material Processing Area.
    - 4.3. (1000 to 1300 Square Foot) Prototyping/Material Processing Area.
    - 4.4. (2000 to 2300 Square Foot) Prototyping/Material Processing Area.
    - 4.5. (2600 Square Foot) Prototyping/Material Processing Area.
    - 4.6. (3000 Square Foot) Prototyping/Material Processing Area.
    - 4.7. (3600 Square Foot) Prototyping/Material Processing Area.
5. Separate Classroom/Lecture Space—(Various Square Footages)
    - 5.1. (500 Square Foot) Classroom/Lecture Space with Raised Stadium Seating.
    - 5.2. (250 to 500 Square Foot) Classroom/Lecture Space-standard student desks.
    - 5.3. (800 to 1000 Square Foot) Classroom/Lecture Space-standard student desks.
6. Various Options
    - 6.1. (250 Square Foot) CNC/CIM/Rapid Prototyping Area
    - 6.2. (100 Square Foot) Testing Lab
    - 6.3. (200 Square Foot) Research/Resource Area
    - 6.4. (350 Square Foot) Video Production Room

Probe Question 2
What types of support spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?

1. Instructor Office Space
    - 1.1. (70 to 100 Square Foot) Instructor Office Space
    - 1.2. (130 to 150 Square Foot) Instructor Office Space
    - 1.3. (200 Square Foot) Instructor Office Space.
2. General Storage
    - 2.1. (75 to 100 Square Foot) General Storage/Supply Room.
    - 2.2. (130 to 150 Square Foot) General Storage/Supply Room.
    - 2.3. (200 to 250 Square Foot) General Storage/Supply Room.
    - 2.4. (400 Square Foot) General Storage/Supply Room.
    - 2.5. (750 Square Foot) General Storage/Supply Room.
3. Project Storage

- 3.1. (144 to 200 Square Foot) Project Storage Room.
- 3.2. (400 to 700 Square Foot) Project Storage Room.

4. Equipment/Tool Storage
   - 4.1. (100 to 150 Square Foot) Equipment/Tool Storage Room.
   - 4.2. (300 Square Foot) Equipment/Tool Storage Room.
   - 4.3. (500 Square Foot) equipment/Tool Storage Room.
5. Various Spaces
   - 5.1. (150 Square Foot) Technology Student Association (TSA) Officer Office.
   - 5.2. (200 Square Foot) Video Development/Editing Quiet Space.
   - 5.3. (100 Square Foot) Server Closet

Probe Question 3
How should each instructional space be furnished for 28 students and 1 instructor?

1. Combination Computer/Lecture/Presentation Area
   - 1.1. (28) Computer Style Chairs
   - 1.2. Bookshelf Storage Case
   - 1.3. Bulletin Board
   - 1.4. Columned Notebook Racks
   - 1.5. Combination CAD/Drafting Student Workstations
   - 1.6. Combination CAD/Drafting Student Workstations with elevated monitors
   - 1.7. Demonstration Station
   - 1.8. Display Cabinet with Shelves
   - 1.9. File Cabinet
   - 1.10. General Drafting Tables
   - 1.11. Instructor Work Station/Desk
   - 1.12. Lockable Storage Cabinet
   - 1.13. Magazine Rack
   - 1.14. Marker Board
   - 1.15. Multimedia Cabinet
   - 1.16. Printer Table.
   - 1.17. Projection Screen
   - 1.18. Projection Table
   - 1.19. Rolling Adjustable Chairs
   - 1.20. Student Chair—not on rollers
   - 1.21. Student Computer Desks
2. One Room Multipurpose Lab
   - 2.1. Computer Tables Computers for every 6 students
   - 2.2. Design Pods with Conference table seating that accommodates 3
   - 2.3. Printer Table
   - 2.4. Round Tables
   - 2.5. Student Chairs
   - 2.6. Teacher Desk
3. Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work
   - 3.1. Activity Storage Cabinet w/Tote Trays
   - 3.2. Adjustable Stools
   - 3.3. Built in Cabinets and Countertops
   - 3.4. Lockable Storage/Supply Cabinets
   - 3.5. Mobile Material and Activity Cart
   - 3.6. Portable Standing-height Shop Style Workbenches
   - 3.7. Printer Table
   - 3.8. Prototype and Testing Stations with Adjustable Stool

- 3.9. Standard-height Student Worktables
- 3.10. Storage Cabinet
- 3.11. Teacher Command Station
- 3.12. Work Stations Similar to Modular Tables

4. Prototyping/Material Processing
   - 4.1. Activity Storage Cabinets w/Tote Trays
   - 4.2. Built in Cabinets and Countertops
   - 4.3. Demonstration Table
   - 4.4. Large Sink
   - 4.5. Lockable Storage/Supply Cabinets
   - 4.6. Mobile Material and Activity Cart
   - 4.7. Storage Lockers for Student Projects.
   - 4.8. Standing-height Shop-Style Workbenches
   - 4.9. Stools
   - 4.10. Tool Storage Cabinet
   - 4.11. Wall Mounted Tool Cabinets
5. Separate Classroom/Lecture Space—(Various Square Footages)
   - 5.1. Book Storage Shelf
   - 5.2. Bulletin Board
   - 5.3. Durable Theater Seating with Writing Surface
   - 5.4. Lockable Storage Cabinets
   - 5.5. Multimedia Cabinet
   - 5.6. Marker Board
   - 5.7. Printer Table
   - 5.8. Projection Screen
   - 5.9. Standard Student Desks
   - 5.10. Teacher Workstation/Desk
6. Various Spaces
   - 6.1. Built-in Countertops for Video Room

Probe Question 4
How should each support space be furnished for 28 students and 1 instructor?

1. Instructor Office Space
   - 1.1. Book/Multimedia Storage Cabinet
   - 1.2. Book Storage Shelves
   - 1.3. Built-in Counter Workspace
   - 1.4. Instructor Desk
   - 1.5. Lockable Filing Cabinet
   - 1.6. Lockable Storage Cabinet
2. General Storage
   - 2.1. Built-in Storage Shelving
   - 2.2. Braced Metal Storage Shelving
   - 2.3. Hanging Hooks
   - 2.4. Large Clear Plastic Bins
   - 2.5. Lockable Storage Cabinet
   - 2.6. Wire Rack Storage Shelving
3. Project Storage
   - 3.1. Cage-type Access Project Storage
   - 3.2. Portable Storage Cabinets
   - 3.3. Portable Wire Shelving Carts with Plastic Organizers
   - 3.4. Shelving Units
   - 3.5. Wire rack Storage Shelving
4. Equipment/Tool Storage
   - 4.1. Built-in Storage Shelving
   - 4.2. Braced Metal Storage Shelving
   - 4.3. Lockable Storage Cabinet
   - 4.4. Wire Rack Storage Shelving

5. Various Spaces
   - 5.1. Technology Student Association (TSA) Book/Multimedia Storage Cabinet
   - 5.2. TSA Book Storage Shelving
   - 5.3. TSA built-in Counter Workspace
   - 5.4. TSA Lockable Filing Cabinet
   - 5.5. (TSA) Lockable Storage Cabinet
   - 5.6. (TSA) Officer Desk
   - 5.7. Video Room Built-in Countertop Workspace

Probe Question 5
What types of safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility?

1. Safety Materials
   - 1.1. Clear Sight-lines within Space for Student Supervision
   - 1.2. Direct Exhaust Vents
   - 1.3. Emergency Shut-Off Switch
   - 1.4. Evacuation Plans
   - 1.5. Eye Wash Station
   - 1.6. Fire Extinguishers
   - 1.7. Fire-Resistant Trash Can
   - 1.8. Flammable Storage Cabinet (Vented)
   - 1.9. General Safety Rules Posted
   - 1.10. Glass Sterilizing/Storage Cabinet
   - 1.11. Hazardous Chemical Storage Cabinet (Vented)
   - 1.12. High-Impact Block Walls
   - 1.13. High-Impact Safety Glass in Divided Areas for Teacher Observation
   - 1.14. Kill Switches for Large Equipment
   - 1.15. Machine Exhaust System
   - 1.16. Machine Specific Safety Rules Posted at Each Machine
   - 1.17. Mounted First Aid Kit
   - 1.18. Paper Towel Rack
   - 1.19. Quick Communication to Main Office
   - 1.20. Regulated Air Connection
   - 1.21. Restroom with Emergency Chemical Shower wt/floor Drain
   - 1.22. Safety Signs
   - 1.23. Sealed Concrete Floors
   - 1.24. Shields/Guards on Machines
   - 1.25. Sink with Soap Dispenser
   - 1.26. VCT in Production and Storage Areas to Minimized Trip Hazards
   - 1.27. Well Marked Safety Zone Areas

Probe Question 6
What types of personal safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility?

1. Personal Safety Materials
   - 1.1. Aprons
   - 1.2. Dust Masks
   - 1.3. Ear Protection
   - 1.4. Eye Protection (Safety Glasses/Goggles)
   - 1.5. Face Shields
   - 1.6. Gloves

1.7. Hair Pulled Back
1.8. Hard Hat
1.9. Protective Clothing
1.10. Respirators with Disposable Filters
1.11. Safety Glasses
1.12. Welding Safety Equipment

Probe Question 7
What types of hand tools are necessary?

1. Hand Tools
    1.1. Adjustable Wrenches
    1.2. Claw Hammer
    1.3. Ball Peen Hammer
    1.4. Bar Clamps
    1.5. Bench Brushes
    1.6. Bolt Cutters
    1.7. C-Clamps
    1.8. Center Punch
    1.9. Cold Chisels
    1.10. Coping Saw
    1.11. Crescent Wrench Set
    1.12. Desoldering Iron
    1.13. Divider
    1.14. Electronics Vise
    1.15. English Allen Wrenches
    1.16. English Wrenches
    1.17. Etching System
    1.18. File Card
    1.19. Flat Head Screwdrivers
    1.20. Hack Saw
    1.21. Hand Drill
    1.22. Hand Seamer
    1.23. Hex Wrenches
    1.24. Hot Glue Guns
    1.25. Level
    1.26. Magnets
    1.27. Metal Files
    1.28. Metal Punch
    1.29. Metric Allen Wrenches
    1.30. Metric Wrenches
    1.31. Nail Set
    1.32. Phillips Screwdrivers
    1.33. Plastic Mallet
    1.34. Pliers
    1.35. Pop Rivet Gun
    1.36. Rubber Mallet
    1.37. Sanding Blocks
    1.38. Scissors
    1.39. Scratch Awl
    1.40. Scribes
    1.41. Socket Set
    1.42. Soldering Equipment
    1.43. Spring Clamps
    1.44. Staple Gun
    1.45. Straight Edges
    1.46. Tin Snips
    1.47. Torque Wrenches
    1.48. Triangles
    1.49. Try Square
    1.50. T-Squares
    1.51. Tweezers
    1.52. Twist Drills
    1.53. Utility Knives
    1.54. Wire Snips
    1.55. Wire Strippers
    1.56. Wood Chisels
    1.57. Wood Files
    1.58. Workbench Vises
    1.59. X-acto Knives

Probe Question 8
What types of hand held power tools are necessary?

1. Power Tools
    1.1. Assorted Air Tools
    1.2. Belt Sander
    1.3. Corded Hand Drill
    1.4. Jig Saw

1.5. Buffer
1.6. Cordless Hand Drill
1.7. Dremel Tool
1.8. Electric Chisels
1.9. Grinder- with Sandpaper
1.10. Grinder- with Wheel
1.11. Hot Air Gun
1.12. Hot Wire Cutter
1.13. Laminate Trimmer Bits
1.14. Orbital Sanders
1.15. Palm Sander
1.16. Plastic Heat Strip
1.17. Plastics Welder
1.18. Pneumatic Nail Gun
1.19. Portaband (for metal Cutting)
1.20. Rotary Cutter
1.21. Router
1.22. Router Bits
1.23. Saws All
1.24. Sheet Metal Shear
1.25. Skill Saw
1.26. Solder Pens
1.27. Solders Gun
1.28. Strip Heater
1.29. Wafer Doweling Tool

Probe Question 9
What types of material processing equipment are necessary?

1. Material Processing Equipment
   1.1. 3D Printer
   1.2. Air Compressor
   1.3. Autonomous Robot
   1.4. Band Saw
   1.5. CIM CELL with Robotic Arm, and Conveyor Belt
   1.6. CNC Lathe
   1.7. CNC Mill
   1.8. CNC Router
   1.9. Combo Belt/Disc Sander
   1.10. Drill Press
   1.11. Foam Cutter
   1.12. Grinder/Wire Wheel Combo
   1.13. Jointer
   1.14. Laser Engraver
   1.15. Metal Band Saw
   1.16. Metal Brake
   1.17. Metal Foot Shear
   1.18. Metal Lathe
   1.19. Metal Slip Rollers
   1.20. MIG Welder
   1.21. Oxy-Acetylene Unit
   1.22. Planer
   1.23. Plastic Injection Molder
   1.24. Plastic Vacuum Forming Machine
   1.25. Plastics Machine (multi-purpose)
   1.26. Radial Arm Saw
   1.27. Scroll Saw
   1.28. Sheet Metal Tools
   1.29. Sliding Compound Miter
   1.30. Small MIG/Arc Welder Combo
   1.31. Spindle Sander
   1.32. Spot Welder
   1.33. Table Saw
   1.34. Table Top Band Saw
   1.35. Table Top Drill Press
   1.36. Table Top Table Saw
   1.37. Thermo Fax Machine
   1.38. Thermo former
   1.39. TIG Welder
   1.40. Vinyl Sign Machine
   1.41. Wood Lathe

Probe Question 10
What types of computer software are necessary?

1. Software
   - 1.1. 2D CAD
   - 1.2. 3D Modeling/Design and Analytical
   - 1.3. Animation
   - 1.4. Architectural Design
   - 1.5. Civil Design
   - 1.6. Classroom Management and Supervision
   - 1.7. Clip Art
   - 1.8. Data Base
   - 1.9. Desktop Publishing
   - 1.10. Dictionary
   - 1.11. Electronic Circuit Design
   - 1.12. Electronics Training and Simulation
   - 1.13. Engineering Training
   - 1.14. Finite Element Modeling
   - 1.15. Gaming Development
   - 1.16. Internet Browser
   - 1.17. MathCAD
   - 1.18. Mechanical Workbench
   - 1.19. Multimedia and Presentation Graphics
   - 1.20. Multimedia Generation and Podcast
   - 1.21. Parallax Basic Stamp PLC Programming
   - 1.22. PC Control
   - 1.23. Sign or Banner Making
   - 1.24. Software for Programming Robots
   - 1.25. Spread Sheet
   - 1.26. Spreadsheet
   - 1.27. VEX Easy C PLC Programming
   - 1.28. Video Editing
   - 1.29. Web-Design
   - 1.30. WestPoint Bridge Builder
   - 1.31. Word Processing

Probe Question 11
What types of audio/visual equipment are necessary?

1. Audio/Visual
   - 1.1. Cable TV Access
   - 1.2. Computer Display-Touch Sensor
   - 1.3. Computer Projection System (LCD Projector and Projection Screen)
   - 1.4. Convex Mirrors for student Supervision
   - 1.5. Digital Camcorder
   - 1.6. Digital Camera
   - 1.7. Document Camera
   - 1.8. DVD Player
   - 1.9. Interactive or Smart Board
   - 1.10. Interactive Tablet
   - 1.11. Scanner
   - 1.12. Scrolling Message Board
   - 1.13. Stereo/CD player and Speakers with surround sound
   - 1.14. TV Set
   - 1.15. VCR
   - 1.16. VCR/DVD Combo player-recorder
   - 1.17. Web Access
   - 1.18. Web Camera
   - 1.19. Wireless Mouse
   - 1.20. Wireless Pointer
   - 1.21. Wireless Room Microphones and Speakers

Probe Question 12
What types of measuring and testing devices are necessary?

1. Measuring and Testing
    - 1.1 Adjustable Triangles
    - 1.2 Altimeter Gun
    - 1.3 Architects Scale
    - 1.4 Computer Interfaced Materials/Structural Tester
    - 1.5 Dial calipers
    - 1.6 Drafting Tools
    - 1.7 Engineering Scale
    - 1.8 Fast Read Thermometers
    - 1.9 Framing Square
    - 1.10 GPS Tracking Device
    - 1.11 Graduated Metal T-Squares
    - 1.12 Hydrometer
    - 1.13 Large Package Shipping Scale (600lbs)
    - 1.14 Laser Level
    - 1.15 Laser Tape Measure
    - 1.16 Level
    - 1.17 Light Guns
    - 1.18 Measuring Tape
    - 1.19 Metal Rulers
    - 1.20 Meter Sticks
    - 1.21 Metric Rulers
    - 1.22 Micrometers
    - 1.23 Multi-Meters
    - 1.24 Oscilloscopes
    - 1.25 PH Sensors
    - 1.26 Postage Scale
    - 1.27 Power Supplies
    - 1.28 Pressure Sensors
    - 1.29 Printer Scale
    - 1.30 Protractors
    - 1.31 Speed Square
    - 1.32 Spring Scales
    - 1.33 Stopwatches
    - 1.34 Strain/Stress Gauge
    - 1.35 Temperature Sensors
    - 1.36 Transit and Fulcrum
    - 1.37 Triple Balance Beam with Weights
    - 1.38 Wind Tunnel
    - 1.39 Wood Rulers

Probe Question 13
How many computers (and computer related equipment) are necessary?

1. Student Computers
    - 1.1. (4) Student Laptops Dedicated for TSA Conference Competitions
    - 1.2. (6) Student Computers
    - 1.3. (7) Computers
    - 1.4. (15) Student Computers
    - 1.5. (1) Computer per Student for a total of (28) student computers
    - 1.6. (30) Student Computers
    - 1.7. (45) Student Computers
    - 1.8. (1) Dedicated Computer for Each CNC Machine (Robot, Mill, Lathe, and 1.9. Laser Engraver) in Addition to the Student Computers

2. Instructor Computers
    - 2.1. (1) Instructor Computer
    - 2.2. (1) Instructor Laptop
    - 2.3. (2) Instructor Computers
    - 2.4. (1) High Powered Demonstration Computer

3. Printers
    - 3.1. (1) Black & White Laser Printer
    - 3.2. (1) Color Laser Printer.
    - 3.3. (1) Large Format CAD Printer/Plotter
    - 3.4. (1-4) Inkjet Printer
    - 3.5. (1-2) Scanner
    - 3.6. (1) Fax

4. General Lab
    - 4.1. (1) Classroom Phone
    - 4.2. (1-2) Dedicated Phone Line
    - 4.3. (1-2) Video Editing Stations
    - 4.4. (1-2) Digital Still Cameras
    - 4.5. (1-2) Camcorders
    - 4.6. Networked Lab with Internet Connection

Probe Question 14
What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, or other engineering related equipment, if any, are necessary?

1. Engineering Equipment
    - 1.1. Alternative Energy Systems Kits and Trainers
    - 1.2. Variety of Robotics Trainers (VEX, Lego Mindstorm, etc.)
    - 1.3. Variety of Electronics Basic Electricity Training Kits (Gibson Tech, Tronix, etc.)
    - 1.4. Automated Manufacturing Equipment
    - 1.5. Civil Engineering Trainer Kit
    - 1.6. Electrical Motor Kits
    - 1.7. Fischer Tech Interfacing
    - 1.8. Hydraulics Trainer
    - 1.9. Mechanisms Trainer
    - 1.10. Pneumatics Trainer
    - 1.11. Precision Measurement Trainer
    - 1.12. Sensors and Transducers Kit
    - 1.13. No Packaged Kits or Trainers are necessary

Probe Question 15
List any other item you feel is necessary for teaching engineering design concepts to high school students.

1. Other Items
    - 1.1. 3 Hole Punch
    - 1.2. Clear Tape
    - 1.3. Collaboration with Math and Science Teachers.
    - 1.4. Colored Markers
    - 1.5. Colored Pencils
    - 1.6. Computer Paper
    - 1.7. Construction Paper
    - 1.8. Dry Erase Markers
    - 1.9. Engineering Design Notebooks
    - 1.10. Glue
    - 1.11. Masking Tape
    - 1.12. Office Supplies
    - 1.13. Paper Cutter
    - 1.14. Partnerships with local manufacturers, business, engineering firms, etc.
    - 1.15. Play Dough
    - 1.16. Reverse Engineering
    - 1.17. Stapler
    - 1.18. State Approved Curriculum

1.19. Tissue Paper	1.21. Waste Paper Baskets
1.20. Turn Key Project Lead the Way Curriculum	1.22. Water Fountain

Round Two

The list of unique responses identified during the Round 1 of this research (see Table 4.4) became the items for consideration in the Round 2 survey instrument (see Appendix E). The online survey was available from June 17 to July 17, 2009.

Participants were contacted via email and directed to access the online survey in order to indicate their level of agreement with each item on a 6-point Likert-type scale (see Appendix F). The Likert scale ranged from: (1) strongly disagree, (2) disagree, (3) somewhat disagree, (4) somewhat agree, (5) agree, to (6) strongly agree. Table 4.5 displays the analyzed results for each item on the Round 2 survey. Twenty-three of the original 24 participants from Round One completed the survey by the July 17 deadline.

Table 4.5

Results of Round Two

Probe Question One: What types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?

ITEM	Mean	Median	SD	IRQ
Combination Computer, Lecture, Presentation Area				
1. (1000 to 1500 Square Foot) Combination Computer, Lecture, Presentation Area	4.23	5	1.5055	4-5
2. (1800 to 2500 Square Foot) Combination Computer, Lecture, Presentation Area	3.95	4	1.7313	5.5-3
Multipurpose Room				
3. (1000 to 1200 Square Foot) Multipurpose Room for Entire Lab.	2.61	2	1.7629	1-4
Flexible Workspace				
4. (250 Square Foot) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work.	1.26	1	0.9500	1-2

5. (1000 to 1200 Square Foot) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work	3.86	4	1.3914	3-5
6. (1800 to 2000 Square Foot) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work	4.39	5	1.2420	3.5-5
7. (2400 to 2600 Square Foot) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work	3.50	4	1.4381	2-5
Prototyping/Material Processing Area				
8. (120 Square Foot) Prototyping/Material Processing Area.	1.62	1	0.8438	1-2
9. (500 to 800 Square Foot) Prototyping/Material Processing Area	2.26	3	1.4302	1-4
10. (1000 to 1300 Square Foot) Prototyping/Material Processing Area	4.09	4	1.0999	4-5
11. (2000 to 2300 Square Foot) Prototyping/Material Processing Area	4.23	4.5	1.2035	3-5
12. (2600 Square Foot) Prototyping/Material Processing Area	3.32	3.5	1.0389	2-4
13. (3000 Square Foot) Prototyping/Material Processing Area	2.33	2	1.0389	2-3
14. (3600 Square Foot) Prototyping/Material Processing Area	1.67	2	0.6424	1-2
Classroom/Lecture Room				
15. (500 Square Foot) Classroom/Lecture Space with Raised Stadium Seating	3.00	3	1.6903	2-5
16. (250 to 500 Square Foot) Classroom/Lecture Space- Standard Student Desks.	2.55	2.5	1.2695	2-3
17. (800 to 1000 Square Foot) Classroom/Lecture Space-Standard student Desks.	4.09	5	1.6658	2.5-5
Additional Instructional Spaces				
18. (250 Square Foot) CNC/CIM/Rapid Prototyping Area	4.50	5	1.3399	4-5
19. (100 Square Foot) Testing Lab	4.41	5	1.3369	3.25-5
20. (200 Square Foot) Research/Resource Area	4.09	4	1.4420	3.5-5
21. (350 Square Foot) Video Production	3.48	4	1.6116	2-5

Probe Question Two: What types of support spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?

ITEM	Mean	Median	SD	IRQ
Instructors Office				
22. (70 to 100 Square Foot) Instructor Office Space	3.64	4	1.6389	2-5
23. (130 to 150 Square Foot) Instructor Office Space	4.26	5	1.3583	2-4
24. (200 Square Foot) Instructor Office Space	2.91	3	1.4113	2-4
General Storage/Supply Room				
25. (75 to 100 Square Foot) General Storage/Supply Room	3.18	3	1.4345	2-4.75
26. (130 to 150 Square Foot) General Storage/Supply Room	3.50	4	1.2340	2.25-4
27. (200 to 250 Square Foot) General Storage/Supply Room	4.45	5	1.3048	4-5
28. (400 Square Foot) General Storage/Supply Room	4.00	4	1.6237	3-5
29. (750 Square Foot) General Storage/Supply Room	3.09	3	1.5347	2-4
Project Storage Room				
30. (144 to 200 Square Foot) Project Storage Room	4.59	5	1.1143	4-5
31. (400 to 700 Square Foot) Project Storage Room	3.61	4	1.3101	2.5-5
Equipment/Tool Storage Room				
32. (100 to 150 Square Foot) Equipment/Tool Storage Room	4.32	5	1.2929	4-5
33. (300 Square Foot) Equipment/Tool Storage Room	3.91	4	1.3111	3-5
34. (500 Square Foot) Equipment/Tool Storage Room.	2.77	2	1.3461	2-3.75
Additional Support Spaces				
35. (150 Square Foot) Technology Student Association	3.70	4	1.5724	2.5-5
36. (200 Square Foot) Video Development/Editing Quiet Space.	3.52	4	1.4407	2-4.5
37. (100 Square Foot) Server Closet	3.59	4	1.7231	2-5

Probe Question Three: How should each instructional space be furnished for 28 students and 1 instructor?

ITEM	Mean	Median	SD	IRQ
Combination Computer, Lecture, Presentation Area				
38. Bookshelf Storage Case	5.36	5	0.4810	5-6
39. Bulletin Board	5.18	5	1.0285	5-6

40. Columned Notebook Racks	3.90	4	1.3768	4-5
41. Combination CAD/Drafting Student Workstations	4.91	5	1.2398	5-6
42. Combination CAD/Drafting Student Workstations with Elevated Monitors	4.09	5	1.5641	3-5
43. Computer Style Chairs	4.52	5	1.1800	4-5
44. Demonstration Station	5.05	5	1.1069	5-6
45. Display Cabinet with Shelves	4.59	5	1.0295	4-5
46. File Cabinet	5.10	5	1.1508	5-6
47. General Drafting Tables	2.82	2	1.6414	1.25-4
48. Instructor Work Station/Desk	5.23	5	0.5979	5-6
49. Lockable Storage Cabinet	5.45	5	0.4979	5-6
50. Magazine Rack	3.90	4	1.3058	3-5
51. Marker Board	5.18	5	0.7158	5-6
52. Multimedia Cabinet	4.82	5	1.0285	5-5
53. Printer Table	5.05	5	0.8779	5-5.75
54. Projection Screen	5.41	6	0.7781	5-6
55. Projection Table	4.70	5	1.4526	4.75-6
56. Rolling Adjustable Chairs	4.14	4	1.2539	3.25-5
57. Student Chair—Not on Rollers	3.91	4	1.5347	3-5
58. Student Computer Desks	4.23	4	1.1651	3.25-5
Multipurpose Room				
59. Computer Tables	4.73	5	1.0523	5-5
60. Design Pods with Conference Table Seating that Accommodates 3 Computers for Every 6 Students	3.82	4	1.6689	2-5
61. Printer Table	5.09	5	0.5961	5-5
62. Round Tables	3.91	4	1.3453	3-5
63. Student Chairs	5.27	5	0.5378	5-6
64. Teacher Desk	5.18	5	0.7158	5-6
Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work				
65. Activity Storage Cabinet w/Tote Trays	4.76	5	0.8677	4-5
66. Adjustable Stools	4.71	5	0.8248	4-5
67. Built-in Cabinets and Countertops	4.29	5	1.5164	4-5
68. Lockable Storage/Supply Cabinets	5.14	5	0.6389	5-5
69. Mobile Material and Activity Cart	4.71	5	1.0302	4-5
70. Portable Standing-height Shop-Style Workbenches	4.38	5	1.2141	4-5
71. Printer Table	4.60	5	1.1136	4.5-5
72. Prototype and Testing Stations with Adjustable Stool	4.57	5	1.1780	4-5
73. Standard-height Student Worktables	4.65	5	1.1079	4-5.25
74. Storage Cabinet	5.19	5	0.5871	5-6
75. Teacher Command Station	4.62	5	0.9500	4-5
76. Work Stations Similar to Modular Tables	3.52	4	1.5620	2-5

ITEM	Mean	Median	SD	IRQ
Prototyping/Material Processing				
77. Activity Storage Cabinets w/Tote Trays	4.86	5	0.8144	5-5
78. Built-in Cabinets and Counter Tops	4.41	5	1.4032	4-5
79. Demonstration Table	4.77	5	1.2768	5-5.75
80. Large Sink	4.73	5	1.0947	5-5
81. Lockable Storage/Supply Cabinets	5.23	5.5	1.0415	5-6
82. Mobile Material and Activity Cart	4.82	5	0.7767	4-5
83. Standing-height Shop-Style Workbenches	4.86	5	0.9674	5-5
84. Stools	4.59	5	1.1143	4-5
85. Storage Lockers for Student Projects	4.86	5	0.9193	4-5.75
86. Tool Storage Cabinet	5.36	5	0.6428	5-6
87. Wall Mounted Tool Cabinets	4.68	5	1.1827	4-5
Separate Classroom/Lecture Space				
88. Book Storage Shelf	4.36	5	1.4938	4-5
89. Bulletin Board	4.64	5	1.5535	5-5.75
90. Durable Theater Seating with Writing Surface	3.41	3	1.8988	1.25-5
91. Lockable Storage Cabinets	4.10	4	1.3058	4-5
92. Marker Board	5.00	5	1.3484	5-6
93. Multimedia Cabinet	4.59	5	1.4666	5-5
94. Printer Table	4.41	5	1.4666	4-5
95. Projection screen	5.00	5	1.4800	5-6
96. Standard Student Desks	3.77	5	1.8570	2-5
97. Teacher Workstation/Desk	4.82	5	1.3361	5-5.75
Additional Instructional Furnishings				
98. Built-in Countertops for Video Room	3.29	4	1.5164	2-5

Probe Question Four: How should each support space be furnished for 28 students and 1 instructor?

ITEM	Mean	Median	SD	IRQ
Instructor Office Space				
99. Book Storage Shelves	5.19	5	0.3927	5-5
100. Book/Multimedia Storage Cabinet	4.76	5	0.9712	4-5
101. Built-in Counter Workspace	3.57	4	1.4983	2-5
102. Instructor Desk	5.24	5	0.6835	5-6
103. Lockable Filing Cabinet	5.05	5	0.7222	5-5
104. Lockable Storage Cabinet	5.43	5	0.4949	5-6
General Storage				
105. Braced Metal Storage Shelving	4.77	5	1.0415	4-5.75
106. Built-in Storage Shelving	4.45	5	1.3392	4-5
107. Hanging Hooks	4.05	4	1.2961	3-5
108. Large Plastic Clear Bins	4.86	5	0.6938	5-5
109. Lockable Storage Cabinet	4.95	5	0.9989	5-6
110. Wire Rack Storage Shelving	4.23	4.5	1.2407	3.25-5

	Project Storage				
111.	Cage-type Access Project Storage	3.68	4	1.3276	3-5
112.	Portable Storage Cabinets	4.05	4	1.0900	4-5
113.	Portable Wire Shelving Carts with Plastic Organizers	4.05	4	1.2961	3.25-5
114.	Shelving Units	5.05	5	0.5622	5-5
115.	Wire Rack Storage Shelving	4.05	5	1.4917	3.25-5
	Equipment/Tool Storage				
116.	Built-in Storage Shelving	4.73	5	0.9621	4-5
117.	Braced Metal Storage Shelving	4.23	5	1.2572	4-5
118.	Lockable Storage Cabinet	5.23	5	0.7343	5-6
119.	Wire Rack Storage Shelving	4.05	5	1.4917	3.25-5
	Various Support Space Furnishings				
120.	Technology Student Association (TSA) Book/Multimedia Storage Cabinet	4.73	5	0.9621	4-5
121.	TSA Book Storage Shelving	3.57	4	1.3653	3-5
122.	TSA built-in Counter Workspace	3.33	4	1.6134	2-4
123.	TSA Lockable Filing Cabinet	3.68	4	1.5192	2.25-5
124.	(TSA) Lockable Storage Cabinet	3.77	4	1.4120	4-5
125.	(TSA) Officer Desk	3.67	4	1.5223	2-5
126.	Video Room Built-in Countertop Workspace	3.10	3	1.4110	2-4

Probe Question Five: What types of facility safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility?

	ITEM	Mean	Median	SD	IRQ
127.	Clear Sight lines within Space for Student Supervision	5.86	6	0.3432	6-6
128.	Direct Exhaust Vents	4.86	5.5	1.4743	4.25-6
129.	Emergency Shut Off Switch	5.55	6	0.8907	5-6
130.	Evacuation Plans	5.77	6	0.4191	6-6
131.	Eye Wash Station	5.36	6	0.9791	5-6
132.	Fire Extinguishers	5.68	6	0.8732	6-6
133.	Fire Resistant Trash Can	5.27	6	1.0082	5-6
134.	Flammable Storage Cabinet (Vented)	5.09	6	1.3453	1-3
135.	General Safety Rules Posted	5.73	6	0.4454	5.25-6
136.	Glass Sterilizing/Storage Cabinet	4.64	5	1.4630	4-6
137.	Hazardous Chemical Storage Cabinet (Vented)	4.91	6	1.5929	4.25-6
138.	High-Impact Block Walls	4.77	5	1.3795	4.25-6
139.	High-Impact Safety Glass in Divided Areas for Teacher Observation	4.91	5.5	1.5048	5-6
140.	Kill Switches for Large Equipment	5.55	6	1.0757	5.25-6
141.	Machine Exhaust System	4.95	5.5	1.4917	5-6

142.	Machine Specific Safety Rules Posted at Each Machine	5.27	6	1.2498	5-6
143.	Mounted First Aid Kit	5.77	6	0.4191	6-6
144.	Paper Towel Rack	5.14	5	0.7565	5-6
145.	Quick Communication to Main Office	5.77	6	0.4191	6-6
146.	Regulated Air Connection	5.18	5	0.8861	5-6
147.	Restroom with Emergency Chemical Shower w/Floor Drain	4.00	4	1.3817	3-5
148.	Safety Signs	5.73	6	0.4454	5.25-6
149.	Sealed Concrete Floors	4.73	5	1.1355	4-6
150.	Shields/Guards on Machines	5.64	6	1.0679	6-6
151.	Sink with Soap Dispenser	5.32	5	0.6998	5-6
152.	VCT in Production and Storage Areas to Minimize Trip Hazards	4.32	5	1.5192	3.25-5
153.	Well-Marked Safety Zone Areas	5.18	6	1.2298	5-6

Probe Question Six: What types of personal safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility?

	ITEM	Mean	Median	SD	IRQ
154.	Aprons	3.86	4	1.3583	3.25-5
155.	Dust Masks	4.68	5	1.2205	4-5
156.	Ear Protection	4.57	5	1.4662	4-5
157.	Eye Protection (Safety Glasses/Goggles)	5.55	6	1.0757	5.25-6
158.	Face Shields	4.36	5	1.3995	4-5
159.	Gloves	3.91	4	1.5048	3-5
160.	Hard Hat	3.18	3	1.1923	2-4
161.	Protective Clothing	3.55	4	1.3392	3-4
162.	Respirators with Disposable Filters	3.57	4	1.3997	3-4
163.	Safety Glasses	5.64	6	1.0679	6-6
164.	Welding Safety Equipment	4.50	5	1.6720	3.25-6

Probe Question Seven: What types of hand tools are necessary?

	ITEM	Mean	Median	SD	IRQ
165.	Adjustable Wrenches	5.10	5	0.7681	5-6
166.	Ball Peen Hammer	4.65	5	0.9631	4-5
167.	Bar Clamps	4.75	5	0.8874	5-5
168.	Bench Brushes	4.74	5	0.9648	4.5-5
169.	Bolt Cutters	4.00	4	1.0000	3-5
170.	C-Clamps	5.05	5	0.7399	5-5.25
171.	Center Punch	4.60	5	1.0677	4-5
172.	Claw Hammer	4.85	5	0.9631	4-5.25
173.	Cold Chisels	4.35	4	0.9097	4-5
174.	Coping Saw	4.75	5	0.9937	4-5
175.	Crescent Wrench Set	5.00	5	0.8729	5-6

176.	Desoldering Iron	4.62	5	0.8985	4-5
177.	Divider	4.43	4	1.0942	4-5
178.	Electronics Vise	4.43	5	0.9548	4-5
179.	English Allen Wrenches	4.90	5	0.8677	5-5
180.	English Wrenches	5.00	5	0.6325	5-5
181.	Etching System	3.33	3	1.2848	2-4
182.	File Card	3.95	4	1.3619	3-5
183.	Flat Head Screwdrivers	5.05	5	1.0900	5-6
184.	Hack Saw	5.19	5	0.9571	5-6
185.	Hand Drill	5.10	5	0.9209	5-6
186.	Hand Seamer	3.95	4	1.1742	3-5
187.	Hex Wrenches	4.95	5	0.9989	4-6
188.	Hot Glue Guns	5.05	5	0.7222	5-6
189.	Level	4.90	5	0.8677	5-5
190.	Magnets	4.33	4	1.1269	4-5
191.	Metal Files	4.95	5	0.8438	4-6
192.	Metal Punch	4.76	5	0.9712	4-5
193.	Metric Allen Wrenches	5.14	5	0.8330	5-6
194.	Metric Wrenches	5.10	5	0.8109	5-6
195.	Nail Set	4.67	5	0.8357	4-5
196.	Phillips Screwdrivers	5.19	5	0.7940	5-6
197.	Plastic Mallet	4.76	5	1.0191	4-5
198.	Pliers	5.24	5	0.8109	5-6
199.	Pop Rivet Gun	4.62	5	1.0900	4-5
200.	Rubber Mallet	5.05	5	0.9500	5-6
201.	Sanding Blocks	4.90	5	0.9712	4-6
202.	Scissors	5.14	5	0.7095	5-6
203.	Scratch Awl	4.52	5	1.2954	4-5
204.	Scribes	4.62	5	1.3265	4-6
205.	Socket Set	5.24	5	0.8109	5-6
206.	Soldering Equipment	5.05	5	0.9500	5-6
207.	Spring Clamps	5.00	5	0.9258	5-6
208.	Staple Gun	4.86	5	1.0817	4-6
209.	Straight Edges	5.29	5	0.6999	5-6
210.	Tin Snips	4.86	5	1.0817	4-6
211.	Torque Wrenches	4.86	5	1.1664	4-6
212.	Triangles	4.90	5	0.8109	4-5
213.	Try Square	4.86	5	0.9897	4-6
214.	T-Squares	4.81	5	1.0519	4-6
215.	Tweezers	4.81	5	0.7940	4-5
216.	Twist Drills	4.81	5	1.0519	4-6
217.	Utility Knives	5.14	5	0.7737	5-6
218.	Wire Snips	5.00	5	1.0235	4-6
219.	Wire Strippers	5.05	5	0.9989	5-6
220.	Wood Chisels	4.62	5	0.9989	4-5
221.	Wood Files	4.76	5	1.0191	4-5

222.	Workbench Vises	4.90	5	0.9209	5-5
223.	X-acto Knives	4.95	5	1.0900	5-6

Probe Question Eight: What types of hand held power tools are necessary?

	ITEM	Mean	Median	SD	IRQ
224.	Assorted Air Tools	4.19	5	1.3669	3-5
225.	Belt Sander	4.76	5	1.0648	4-6
226.	Buffer	3.86	4	1.1664	4-4
227.	Corded Hand Drill	4.57	5	1.2178	4-5
228.	Cordless Hand Drill	5.24	5	0.8109	5-6
229.	Dremel Tool	4.86	5	0.9897	5-5
230.	Electric Chisels	3.24	3	1.1086	2-4
231.	Grinder- with Sandpaper	4.38	5	1.1742	4-5
232.	Grinder- with Wheel	4.76	5	1.0191	4-5
233.	Hot Air Gun	4.10	4	1.2207	3.75-5
234.	Hot Wire Cutter	4.43	5	1.1780	4-5
235.	Jig Saw	5.00	5	0.9759	5-6
236.	Laminate Trimmer Bits	3.86	4	1.4892	3-5
237.	Orbital Sanders	4.38	5	1.3965	4-5
238.	Palm Sander	4.57	5	1.1369	4-5
239.	Plastic Heat Strip	4.24	5	1.3058	3-5
240.	Plastics Welder	4.10	4	1.1790	4-5
241.	Pneumatic Nail Gun	3.67	4	1.6997	2-5
242.	PortaBand (for metal Cutting)	4.24	5	1.2688	4-5
243.	Rotary Cutter	3.95	5	1.6176	2-5
244.	Router	4.29	5	1.3502	4-5
245.	Router Bits	4.29	5	1.3502	4-5
246.	Saws All	4.29	4	1.1606	4-5
247.	Sheet Metal Shear	4.29	5	1.5164	4-5
248.	Skill Saw	4.67	5	0.8909	4-5
249.	Solder Pens	4.52	5	1.2196	4-5
250.	Solders Gun	4.76	5	0.8677	4-5
251.	Strip Heater	4.38	5	1.2527	4-5
252.	Wafer Doweling Tool	3.45	3.5	1.4654	2-4.25

Probe Question Nine: What types of material processing equipment are necessary?

	ITEM	Mean	Median	SD	IRQ
253.	3D Printer	4.62	5	1.2901	4-6
254.	Air Compressor	4.81	5	0.9060	4-5
255.	Autonomous Robot	4.10	5	1.3058	3-5
256.	Band Saw	4.86	5	1.1249	5-6
257.	CIM CELL with Robotic Arm, and Conveyor Belt	4.29	5	1.3145	4-5
258.	CNC Lathe	4.52	5	1.0057	4-5
259.	CNC Mill	4.52	5	1.0057	4-5
260.	CNC Router	4.48	5	1.0519	4-5

261.	Combo Belt/Disc Sander	4.57	5	1.2178	4-5
262.	Drill Press	5.19	5	0.9060	5-6
263.	Foam Cutter	4.81	5	1.1389	5-5
264.	Grinder/Wire Wheel Combo	4.43	5	1.2936	4-5
265.	Jointer	4.10	4	1.5089	3-5
266.	Laser Engraver	4.00	4	1.4475	3-5
267.	Metal Band Saw	4.62	5	1.0455	4-5
268.	Metal Brake	4.14	4	1.2454	3-5
269.	Metal Foot Shear	3.95	4	1.7313	2.5-5.5
270.	Metal Lathe	4.00	4	1.2344	3-5
271.	Metal Slip Rollers	3.76	4	1.3768	3-5
272.	MIG Welder	3.95	4	1.3619	3-5
273.	Oxy-Acetylene Unit	3.18	4	1.4349	3-5
274.	Planer	3.71	4	1.4522	3-5
275.	Plastic Injection Molder	4.10	4	1.1914	4-5
276.	Plastic Vacuum Forming Machine	4.14	4	1.2066	4-5
277.	Plastics Machine (multi-purpose)	4.24	5	1.3418	4-5
278.	Radial Arm Saw	4.10	5	1.5401	4-5
279.	Scroll Saw	4.48	5	1.0963	4-5
280.	Sheet Metal Tools	4.48	5	1.1389	4-5
281.	Sliding Compound Miter	4.38	5	1.2527	4-5
282.	Small MIG/Arc Welder Combo	3.76	4	1.3418	3-5
283.	Spindle Sander	3.52	3	1.2954	3-5
284.	Spot Welder	3.81	4	1.4013	3-5
285.	Table Saw	4.57	5	1.2936	4-5
286.	Table Top Band Saw	4.71	5	1.1606	5-5
287.	Table Top Drill Press	4.81	5	1.0519	5-5
288.	Table Top Table Saw	4.63	5	1.0863	5-5
289.	Thermo Fax Machine	3.52	4	1.2581	3-5
290.	Thermo former	3.70	4	1.2288	3-5
291.	TIG Welder	3.19	3	1.4677	2-4
292.	Vinyl Sign Machine	3.62	4	1.3965	2-5
293.	Wood Lathe	3.19	3	1.4013	2-4

Probe Question Ten: What types of computer software are necessary?

	ITEM	Mean	Median	SD	IRQ
294.	2D CAD	4.29	5	1.3851	3-5
295.	3D Modeling/Design and Analytical	5.38	6	0.7854	5-6
296.	Animation	4.71	5	1.1188	4-5
297.	Architectural Design	4.90	5	0.9209	5-5
298.	Civil Design	4.14	4	0.9404	4-5
299.	Classroom Management and Supervision	4.62	5	1.2527	4-5
300.	Clip Art	4.43	5	1.2527	4-5
301.	Data Base	4.71	5	0.8248	4-5
302.	Desktop Publishing	4.90	5	0.9712	5-5

303.	Dictionary	3.76	4	1.2688	3-5
304.	Electronic Circuit Design	4.90	5	1.1086	5-6
305.	Electronics Training and Simulation	4.71	5	0.9828	4-5
306.	Engineering Training	5.00	5	0.7071	5-5
307.	Finite Element Modeling	4.35	4	1.1079	4-5
308.	Gaming Development	3.90	4	1.3418	3-5
309.	Internet Browser	5.57	6	0.4949	5-6
310.	MathCAD	4.25	4	1.0897	4-5
311.	Mechanical Workbench	4.35	4.5	1.1079	4-5
312.	Multimedia and Presentation Graphics	5.24	5	0.6835	5-6
313.	Multimedia Generation and Podcast	4.52	5	1.0057	4-5
314.	Parallax Basic Stamp PLC Programming	4.25	5	1.4098	4-5
315.	PC Control	4.60	5	0.8000	4-5
316.	Sign or Banner Making	3.95	4	1.1169	3-5
317.	Software for Programming Robots	4.95	5	1.1169	5-6
318.	Spread Sheet	5.24	5	0.6835	5-6
319.	VEX Easy C PLC Programming	4.60	5	1.1136	4-5
320.	Video Editing	4.14	5	1.4892	4-5
321.	Web-Design	4.35	5	1.2359	4-5
322.	WestPoint Bridge Builder	4.81	5	0.7315	4-5
323.	Word Processing	5.52	6	0.4994	5-6

Probe Question Eleven: What types of audio visual equipment are necessary?

	ITEM	Mean	Median	SD	IRQ
324.	Cable TV Access	4.23	4	1.1254	4-5
325.	Computer Display-Touch Sensor	3.90	4	1.1914	3-5
326.	Computer Projection System (LCD Projector and Projection Screen)	5.41	5.5	0.7173	5-6
327.	Convex Mirrors for Student Supervision	3.95	4	1.3619	3-5
328.	Digital Camcorder	5.00	5	0.6901	5-5
329.	Digital Camera	4.86	5	1.0817	5-5
330.	Document Camera	3.90	4	1.3768	3-5
331.	DVD Player	4.81	5	1.0963	5-5
332.	Interactive or Smart Board	4.64	5	1.0679	4-5
333.	Interactive Tablet	4.33	4	1.1269	4-5
334.	Scanner	4.95	5	0.7854	5-5
335.	Scrolling Message Board	3.52	4	1.1389	3-4
336.	Stereo/CD Player and Speakers with Surround-Sound	3.90	4	1.1086	4-5
337.	TV Set	4.19	5	1.2954	4-5
338.	VCR	3.25	3.5	1.5772	2-4
339.	VCR/DVD Combo Player-Recorder	4.67	5	1.2084	4-5
340.	Web Access	5.45	5	0.4979	5-6

341.	Web Camera	4.60	5	1.2806	4-5.25
342.	Wireless Mouse	4.75	5	1.2600	4-6
343.	Wireless Pointer	4.30	5	1.3077	3.75-5
344.	Wireless Microphones & Speakers	4.25	4	1.1347	4-5

Probe Question Twelve: What types of measuring and testing devices are necessary?

	ITEM	Mean	Median	SD	IRQ
345.	Adjustable Triangles	4.62	5	0.9989	4-5
346.	Altimeter Gun	4.29	5	1.2778	3-5
347.	Architects Scale	5.00	5	0.9258	5-6
348.	Computer Interfaced Materials/Structural Tester	3.95	4	0.7854	4-4
349.	Dial calipers	5.05	5	0.7222	5-5
350.	Drafting Tools	4.67	5	1.1269	4-5
351.	Engineering Scale	5.14	5	0.7737	5-6
352.	Fast Read Thermometers	4.67	5	0.9428	4-5
353.	Framing Square	4.48	4	0.9571	4-5
354.	GPS Tracking Device	4.24	4	1.2307	4-5
355.	Graduated Metal T-Squares	4.24	4	1.2307	4-5
356.	Hydrometer	4.10	5	1.1508	3-5
357.	Large Package Shipping Scale (600lbs)	3.57	4	1.3653	3-5
358.	Laser Level	4.33	4	1.1269	4-5
359.	Laser Tape Measure	4.29	4	1.1606	4-5
360.	Level	4.67	5	1.0389	4-5
361.	Light Guns	3.95	4	1.0712	3-5
362.	Measuring Tape	5.29	5	0.5471	5-6
363.	Metal Rulers	5.10	5	1.0191	5-6
364.	Meter Sticks	5.24	5	0.4259	5-5
365.	Metric Rulers	5.24	5	0.4259	5-5
366.	Micrometers	5.25	5	0.6982	5-6
367.	Multi-Meters	5.19	5	0.7940	5-6
368.	Oscilloscopes	4.57	5	1.1369	4-5
369.	PH Sensors	4.14	4	1.2066	3-5
370.	Postage Scale	4.15	4.5	1.4239	3.75-5
371.	Power Supplies	5.00	5	0.8367	4.75-6
372.	Pressure Sensors	4.62	5	1.3619	4-6
373.	Printer Scale	4.20	5	1.4697	3-5
374.	Protractors	5.00	5	0.7746	5-5.25
375.	Speed Square	3.90	4	1.5133	3-5
376.	Spring Scales	4.62	5	1.2901	4-5
377.	Stopwatches	5.05	5	0.8438	5-6
378.	Strain/Stress Gage	5.00	5	0.9759	5-6
379.	Temperature Sensors	4.95	5	1.0455	5-6
380.	Transit and Fulcrum	4.48	4	1.0519	4-5
381.	Triple Balance Beam with Weights	4.62	5	1.0900	4-5

382.	Wind Tunnel	4.43	5	1.3299	4-5
383.	Wood Rulers	4.05	4.5	1.5322	3-5

Probe Question Thirteen: How many computers (and computer related equipment) are necessary?

	ITEM	Mean	Median	SD	IRQ
	Student Computers				
384.	(4) Student Laptops Dedicated for TSA conference competitions	4.40	5	1.4967	3.75-6
385.	(6) Student Computers	1.95	1	1.2141	1-3
386.	(7) Computers	2.10	2	1.4110	1-3
387.	(15) Student Computers	3.14	3	1.6983	2-4
388.	(1) Computer Per Student for a Total of (28) Student Computers	5.09	6	1.2026	4.25-6
389.	(30) Student Computers	4.00	5	1.5736	3-5
390.	(45) Student Computers	2.00	2	1.1402	1-3
391.	(1) Dedicated Computer for Each CNC Machine (Robot, Mill, Lathe, and Laser Engraver) in Addition to the Student Computers	4.65	5	1.4239	4-6
	Instructor Computers				
392.	(1) Instructor Computer	5.43	6	0.8492	5-6
393.	(1) Instructor Laptop	5.40	6	0.9695	4.75-6
394.	(2) Instructor Computers	4.26	5	1.5163	3.5-5
395.	(1) High Powered Demonstration Computer	4.90	5	1.0909	4-6
	Printers				
396.	(1) Black & White Laser Printer	5.15	5	0.7921	4.75-6
397.	(1) Color Laser Printer	5.33	5	0.7766	5-6
398.	(1) Large Format CAD Printer/Plotter	5.10	5	1.2307	5-6
399.	(1-4) Inkjet Printer	3.95	4	1.6050	2.5-5
400.	(1-2) Scanner	5.14	5	0.7737	5-6
401.	(1) Fax	3.53	3	1.3126	3-4
	General Lab				
402.	(1) Classroom Phone	5.29	6	0.9828	5-6
403.	(1-2) Dedicated Phone Line	4.57	5	1.3299	4-6
404.	(1-2) Video Editing Stations	3.95	4	1.3619	3-5
405.	(1-2) Digital Still Cameras	5.14	5	0.7737	5-6
406.	(1-2) Camcorders	5.00	5	0.8729	4-6
407.	Networked lab with Internet Connection	5.67	6	0.5634	5-6

Probe Question Fourteen: What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, and any other engineering related equipment if any are necessary?

	ITEM	Mean	Median	SD	IRQ
408.	Alternative Energy Systems Kits and Trainers	4.10	4	1.5089	3-5
409.	Automated Manufacturing Equipment	4.24	5	1.4110	4-5
410.	Civil Engineering Trainer Kit	3.76	4	1.3965	4-5
411.	Electrical Motor Kits	4.05	4	1.3519	4-5
412.	Fischer Tech Interfacing	3.65	4	1.3519	2.75-4.25
413.	Hydraulics Trainer	3.71	4	1.5779	2-5
414.	Mechanisms Trainer	3.76	4	1.5707	2-5
415.	No Packaged Kits or Trainers are Necessary	3.24	3	1.7431	2-5
416.	Pneumatics Trainer	3.74	3	1.6493	2-5
417.	Precision Measurement Trainer	3.90	4	1.5089	3-5
418.	Sensors and Transducers Kit	4.29	5	1.4846	4-5
419.	Variety of Electronics Basic Electricity Training Kits (Gibson Tech, Tronix, etc.)	4.62	5	1.3965	4-6
420.	Variety of Robotics Trainers (VEX, Lego Mindstorm, etc.)	4.71	5	1.4190	4-6

Probe Question Fifteen: List any other item you feel is necessary for teaching engineering design concepts to high school students.

	ITEM	Mean	Median	SD	IRQ
421.	3 Hole Punch	4.90	5	0.8109	4-5
422.	Clear Tape	5.14	5	0.6389	5-6
423.	Collaboration with Math and Science Teachers	5.52	6	06633	5-6
424.	Colored Markers	5.10	5	0.7499	5-6
425.	Colored Pencils	4.81	5	0.9060	4-5
426.	Computer Paper	5.38	5	0.5754	5-6
427.	Construction Paper	4.76	5	1.1014	4-6
428.	Dry-Erase Markers	5.43	5	0.4949	5-6
429.	Engineering Design Notebooks	5.52	6	0.5871	5-6
430.	Glue	5.19	5	0.7315	5-6
431.	Masking Tape	5.19	5	0.6633	5-6
432.	Office Supplies	5.45	5	0.4975	5-6
433.	Paper Cutter	5.19	5	0.7315	5-6
434.	Partnerships with Local Manufacturers, Business, Engineering Firms, etc	5.52	6	0.4994	5-6
435.	Play Dough	3.48	4	1.4349	2-4
436.	Reverse Engineering	4.86	5	0.9404	4-6
437.	Stapler	5.24	5	0.6835	5-6

438.	State Approved Curriculum	4.76	5	1.3768	4-6
439.	Tissue Paper	4.48	5	0.9060	4-5
440.	Turn Key Project Lead the Way Curriculum	3.95	5	1.9875	1-6
441.	Waste Paper Baskets	5.43	6	0.6598	5-6
442.	Water Fountain	4.27	5	1.5428	4-5

Round Two Additions and Comments

The Round 2 survey also included space for participants to add items they felt should be included in order to more fully answer the questions within the survey instrument. Table 4.6 displays the comments and new survey items submitted by participants during Round 2.

Table 4.6

Round Two Additions and Comments

Number	Participant Comment
Probe Question 1	
Combination Computer/Lecture	
1.	The lecture area is a key component to produce large areas of interaction/demonstration.
2.	If this space would be in addition to the one room multipurpose lab, then I would disagree for both sizes.
3.	1800 to 2500 is too much space assuming there will be more to the facility.
One Room Multi-Purpose	
1.	I am answering these questions with the framing of "critical and necessary" rather than "ideal."
2.	I'm figuring 80 sq ft. per student generalized to accommodating various equipment with some safety zones; about 2,200 - if this is a one room multipurpose lab.
Flexible Workspace	
1.	250 square feet of your 1000 to 1200 square foot multipurpose lab might need to be dedicated to project staging; the full 1000 to 1200 of the multipurpose lab should be usable for these purposes (but I don't think you would need this in addition to the multipurpose lab).
2.	It is difficult to have all of these items in a small space. It would be ok as long as there is separate Prototyping Lab.
3.	If this is in place of the multipurpose lab from the item above, then I'm back to about 80 sq. ft. per student.
4.	New Item: Somewhere between 1200 and 1800.

Prototyping

1. Here it depends on what you consider prototyping to encompass; I use a very broad definition of prototyping that would include using construction paper and tape to give people a rough idea of the "thing" one is working on. Again, you could use 120 sq. ft. of your multipurpose room for staging/holding area; you could use your 1000-1200 square foot multipurpose room for prototyping, but wouldn't need a separate/additional space beyond the multipurpose room.
2. Safety zones for machines and work benches for 28 students take up a lot of space.

Separate Classroom

1. The classroom should be part of the computer design area. It is wasteful to do otherwise.
2. With this question, I am keying in on the "separate" space-- so I do not think you need a separate space that is different from/in addition to the multi-purpose room.
3. Theater seating is not flexible enough.

Various Spaces

1. There should be plenty of space in the lab designations previously marked for these areas. There does not need to be separate enclosed areas for these experiences. You must always be ready to delete an old technological tool and replace with the new.
2. You could use some of the multipurpose room for resources, equipment for testing-- I think the numbers listed are high, though, for simply storing some resources/equipment. Also, I think there could be a lot of overlap between each of the small spaces in the previous items, so that you have one small space that accomplishes all/most of these small space functions.

Probe Question 2

Instructor Office

1. It is great to have a room to lock personal belongings, specialized tools, and original software.
2. Live with less here, most teacher don't get an office.

General Storage

1. I don't know that this would necessarily need to be separate from the multipurpose room. Also, this seems to overlap with the small spaces from the items on the previous page.
2. 5 classes worth of supplies need plenty of storage.
3. A good storage space is very important.

Project Storage

1. Would not be necessary to have this in addition to general storage, but project storage likely should be incorporated in general storage.
2. I know it doesn't happen often but, space for it is ideal.
3. Project storage for individual classes would be nice.

Equipment and Tool

1. I see this as being a part of the general storage, but not in addition.
2. This would depend on the storage method.

Various Spaces

1. Server closet can be reduced in size.
2. Some of these things would be nice, but not necessary or critical.

3. TSA officer office allows the officers to be in charge of their organization.

Probe Question 3

1. Unless there are two teachers, the CAD station can be combined with the computer desk.
2. Round tables don't seem to be big enough.
3. Go for the most flexibility.
4. It would be nice to have testing stations separate from workbenches were glue, nails, clamps, hammers, etc. are used and can damage testing stations.
5. A lot of times when students work on a project as a group, they choose to stand. Standing height tables would be great.
6. Durability, security, and flexibility, are my criteria in that order.

Probe Question 4

1. Some schools have teacher cubicles with laptops and a locker for each teacher.
2. As long as the shelving is industrial grade it doesn't matter which type is used.
3. Cage type with locking door, be specific one locked cage per class would be most ideal.

Probe Question 5

1. For the most part, I think that the safety materials that are necessary and critical for this particular environment are the same as the safety materials necessary for any other high school room. If you go beyond what is necessary and critical in terms of the equipment/activities you have in the room, then you will need to add the appropriate additional safety materials. Again, my frame of reference is Microsoft Office, white boards, paper and scissors. No fire, no chemicals, no large machines.

Probe Question 6

1. It just depends on what you want to do. For an engineering curriculum, some heavy work can sent out for manufacturing.

Probe Question 7

1. The extent to which any single tool is critical in an engineering curriculum depends on what needs to be done. It's critical that there are tools for general capability.

Probe Question 8

1. None for this question.

Probe Question 9

1. Some of this equipment is better for prototyping a student design than are others.

Probe Question 10

1. None for this question.

Probe Question 11

1. Cable access & television feed can be provided through data cabling.

Probe Question 12

1. For some of these, in general they might not be necessary or critical, but for a particular project they would be. At that point, it would be matters of whether the teacher was able to/wanted to do a different lesson vs. make sure they have any one particular item.

Probe Question 13

1. Instructor Computer is needed in each work room. (computer lab, prototyping lab and classroom)
2. I agree with video editing but I totally disagree with video production news room settings. This is not in our arena anymore. Video is great for engineering projects only. We should not try to be the video teacher for our schools.

Probe Question 14

1. None for this question.

Probe Question 15

1. None for the question.

Round 3 (Final Round)

The final probe for this research was Round 3. The Round 3 survey instrument (see Appendix G) was available online from August 15, 2009 to August 31, 2009. Participants were contacted via email (see Appendix H) and directed to access the online survey in order to indicate their level of agreement with each item on a 6-point Likert scale. Each participant was emailed Round 2 survey responses to remind them of the previous choices. The 23 participants who completed Round 2 also completed this survey by the deadline. The survey contained all survey items from Round 2, along with statistical data. The mean, median, standard deviation and inter-quartile range were calculated for each item and displayed for the participants. At this point, a numeric score was also displayed alongside each choice so that the statistical data would be readily understood by participants. This allowed participants to see how others in the sample group responded in Round 2. This data gave participants a chance to revise their responses in light of the group response to the same items. Questions from the Round 3 survey instrument were represented in the following format:

What Types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. *1000 to 1500 Sq. Ft. Combination Computer/Lecture/Presentation Area (Round Two Data: Mean= 4.23, Median=5, Min=5, St. Dev.= 1.5055, IQR= 4-5)*

As in round 2, participants ranked their level of agreement on a 6-point Likert scale. The scale ranged from: (1) strongly disagree, (2) disagree, (3) somewhat disagree, (4) somewhat agree (5) agree, to (6) strongly agree. In addition to the original 442 items and corresponding statistical data, two new items, suggested by participants in Round 2, were added to the Round 3 survey instrument for a total of 444 items. Since 2 items were new, they were identified as such and had no statistical data brought forward from the previous round.

The final results for each item appear below in Table 4.7. In addition to the mean, median, standard deviation, and inter-quartile range scores, the mean shift or change during the previous round was reported for each item and is represented by Δ Mean. This score indicates the degree of stability for each individual item, while the IQR indicates the level of consensus afforded the item by the participants.

As described in the chapter 3 of this study, an IQR score of ≤ 1 is considered to be an indication that the item has reached an acceptable degree of consensus. A mean shift (or Δ Mean) of < 15% is an indication that the item can be considered stable.

The literature was vague as to the method used in attributing different levels of significance to the statistical scores that result from Delphi studies. Based upon personal correspondence with Wicklein (September, 3, 2009) and Rojewski (September 5, 2009), a decision was made to maintain the highest standards for the purpose of this study. It was determined that applying the most stringent criteria to the data resulting from the Delphi process would ensure that only items that were undeniably very important would be placed in the highest category and considered in the conclusions and recommendations.

All other items would fall into a secondary category of lesser importance. Items considered to be very important for the purposes of this research met each of the following criteria:

1. An inter-round mean Δ of <15% (indicating stability)
2. A median score of 5 or 6 (indicating a strong level of agreement among participants)
3. An IQR range of ≤ 1 (indicating consensus)

Two hundred sixty-eight (268) items met these strict requirements and are identified in Table 4.7 with double asterisk (**) symbols. Of the 268 items 14 were furniture items from instructional spaces found to be not significant. These will be excluded from significant items in later tables leaving 256 items that met the strictest requirement. Only these items that met the strictest requirements would be considered valid for determining the instructional laboratory facility requirements critical for including engineering design in the engineering and technology education facility.

Table 4.7

Results of Round Three

Probe Question One: What types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?

ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
Combination Computer, Lecture, Presentation Area					
1. **(1000 to 1500 Square Foot) Combination Computer, Lecture, Presentation Area	4.87	0.15	5	0.4476	5-5
2. (1800 to 2500 Square Foot)	2.84	-0.28	3	1.1362	2-4

	Combination Computer, Lecture, Presentation Area					
			Multipurpose Room			
3.	(1000 to 1200 Square Foot) Multipurpose Room for Entire Lab.	2.91	0.11	2.5	1.5929	2-4.75
			Flexible Workspace			
4.	(250 Square Foot) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work.	2.27	0.65	2	1.2856	1-3
5.	(1000 to 1200 Square Foot) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work	3.27	-0.15	3	1.387	2-4
6.	(1800 to 2000 Square Foot) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work	3.59	-0.18	4	1.3704	2.25-4.75
7.	(2400 to 2600 Square Foot) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work	2.55	-0.27	2	1.1571	2-3
8.	**New Item(1200-1800 Square Foot Space) Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work	4.41	n/a	5	1.5273	4-5
			Prototyping/Material Processing Area			
9.	(120 Square Foot) Prototyping/Material Processing Area	1.43	-0.12	1	0.5832	1-2
10.	(500 to 800 Square Foot) Prototyping/Material Processing Area	2.70	0.03	2	1.4872	2-3.5
11.	**(1000 to 1300 Square Foot) Prototyping/Material Processing Area	4.35	0.06	5	1.3058	4-5
12.	**(2000 to 2300 Square Foot) Prototyping/Material Processing Area	4.35	0.03	5	1.3387	4-5

13. (2600 Square Foot) Prototyping/Material Processing Area	2.73	-0.18	2	1.3877	2-4
14. (3000 Square Foot) Prototyping/Material Processing Area	1.96	-0.16	2	0.8064	1-2
15. (3600 Square Foot) Prototyping/Material Processing Area	1.65	-0.01	2	0.6331	1-2
Classroom/Lecture Room					
16. (500 Square Foot) Classroom/Lecture Space with Raised Stadium Seating	2.91	-3.09	2	1.6903	2-4
17. (250 to 500 Square Foot) Classroom/Lecture Space-Standard Student Desks	2.39	-2.70	2	1.1699	2-3
18. (800 to 1000 Square Foot) Classroom/Lecture Space-Standard Student Desks	3.39	-4.78	4	1.5531	2-5
Additional Instructional Spaces					
19. **(250 Square Foot) CNC/CIM/Rapid Prototyping Area	4.30	-0.04	5	1.2661	4-5
20. (100 Square Foot) Testing Lab	3.95	-0.10	4	1.2239	3.25-5
21. **(200 Square Foot) Research/Resource Area	4.39	0.07	5	0.8203	4-5
22. (350 Square Foot) Video Production	2.91	-0.16	2	1.3485	2-4

Probe Question Two: What types of support spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?

ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
Instructors Office					
23. (70 to 100 Square Foot) Instructor Office Space	3.70	0.02	4	1.4872	2-5
24. (130 to 150 Square Foot) Instructor Office Space	3.95	-0.07	4	1.5805	3.25-5
25. (200 Square Foot) Instructor Office Space	2.41	-0.17	2	0.9371	2-3
General Storage/Supply Room					
26. (75 to 100 Square Foot) General Storage/Supply Room	2.57	-0.19	2	1.0561	2-3

27. (130 to 150 Square Foot) General Storage/Supply Room	3.22	-0.08	3	0.9305	2.5-4
28. **(200 to 250 Square Foot) General Storage/Supply Room	4.68	0.05	5	0.8194	4-5
29. (400 Square Foot) GeneralStorage/Supply Room	3.50	-0.13	4	1.2703	2-5
30. (750 Square Foot) General Storage/Supply Room	2.35	-0.24	2	1.0471	2-3
Project Storage Room					
31. (144 to 200 Square Foot) Project Storage Room	4.18	-0.09	4.5	1.0718	3.35-5
32. (400 to 700 Square Foot) Project Storage Room	3.14	-0.13	3	1.0572	2-4
Equipment/Tool Storage Room					
33. **(100 to 150 Square Foot) Equipment/Tool Storage Room	4.70	0.09	5	0.9526	4-5
34. (300 Square Foot) Equipment/Tool Storage Room	3.17	-0.19	3	1.0066	2.5-4
35. (500 Square Foot) Equipment/Tool Storage Room.	2.22	-0.29	2	0.8318	2-3
Additional Support Spaces					
36. (150 Square Foot) Technology Student Association	3.13	-0.15	3	1.3288	2-4
37. (200 Square Foot) Video Development/Editing Quiet Space	3.43	-0.02	4	1.3457	2.5-4.5
38. (100 Square Foot) Server Closet	3.78	0.05	4	1.1779	3-5

Probe Question Three: How should each instructional space be furnished for 28 students and 1 instructor?

ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
Combination Computer, Lecture, Presentation Area					
39. **Bookshelf Storage Case	5.04	-0.06	5	0.8064	5-5
40. **Bulletin Board	5.22	0.01	5	0.5070	5-5.5
41. Columned Notebook Racks	3.73	-0.05	4	1.3205	3-5
42. **Combination CAD/Drafting Student Workstations	4.91	0.00	5	0.9741	5-5.5
43. Combination CAD/Drafting Student Workstations with Elevated Monitors	4.22	0.03	5	1.2839	3.5-5
44. **Computer Style Chairs	4.52	0.00	5	1.0982	4-5
45. Demonstration Station	4.78	-0.05	5	1.1016	4-5.5
46. **Display Cabinet with Shelves	4.43	-0.03	5	1.1354	4-5
47. **File Cabinet	5.04	-0.01	5	0.9991	5-5.5
48. General Drafting Tables	2.62	-0.07	2	1.2141	2-3

49. **Instructor Work Station/Desk	5.36	0.03	5	0.6428	5-6
50. **Lockable Storage Cabinet	5.32	-0.02	5	0.6998	5-6
51. Magazine Rack	3.71	-0.05	4	0.9331	3-4
52. **Marker Board	5.17	0.00	5	0.7011	5-6
53. **Multimedia Cabinet	4.48	-0.07	5	1.0982	4-5
54. **Printer Table	4.86	-0.04	5	0.7095	5-5
55. **Projection Screen	5.26	-0.03	5	0.5289	5-6
56. Projection Table	4.09	-0.13	4.5	1.4113	4-5
57. **Rolling Adjustable Chairs	4.43	0.07	5	1.1731	4-5
58. Student Chair—Not on Rollers	3.65	-0.07	4	1.0471	3-4
59. Student Computer Desks	3.83	-0.09	4	1.0896	3-4
One Room Multipurpose Room					
60. **Computer Tables	4.64	-0.02	5	0.08282	4-5
61. Design Pods with Conference Table Seating that Accommodates 3 Computers for Every 6 Students	3.83	0.00	4	1.6666	3-5
62. **Printer Table	4.96	-0.03	5	0.5500	5-5
63. Round Tables	3.61	-0.08	4	0.9664	3-4
64. **Student Chairs	5.09	-0.03	5	0.5961	5-5
65. **Teacher Desk	5.04	-0.03	5	0.7506	5-5.5
Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work					
66. **Activity Storage Cabinet w/Tote Trays	4.61	-0.03	5	0.9664	4-5
67. **Adjustable Stools	4.65	-0.01	5	0.8134	4.5-5
68. Built-in Cabinets and Countertops	4.17	-0.03	5	1.2735	3.5-5
69. **Lockable Storage/Supply Cabinets	5.17	0.01	5	0.7606	5-6
70. **Mobile Material and Activity Cart	4.43	-0.06	5	0.9244	4-5
71. Portable Standing-height Shop-Style Workbenches	4.17	-0.05	4	0.8674	3.5-5
72. **Printer Table	4.70	0.02	5	0.8041	4.5-5
73. **Prototype and Testing Stations with Adjustable Stool	4.74	0.04	5	0.6736	4-5
74. **Standard-height Student Worktables	4.65	0.00	5	0.4763	4-5
75. **Storage Cabinet	5.04	-0.03	5	0.6240	5-5
76. **Teacher Command Station	4.82	0.04	5	0.9833	4-5.75
77. Work Stations Similar to Modular tables	3.52	0.00	3	1.0159	3-5
Prototyping/Material Processing					
78. **Activity Storage Cabinets w/Tote Trays	4.65	-0.04	5	0.7581	4-5
79. Built-in Cabinets and Countertops	4.17	-0.05	5	1.0066	3.5-5
80. **Demonstration Table	4.55	-0.05	5	0.9875	4-5
81. **Large Sink	4.78	0.01	5	0.7778	4.5-5

82. **Lockable Storage/Supply Cabinets	5.09	-0.03	5.5	1.0178	5-6
83. **Mobile Material and Activity Cart	4.48	-0.07	5	0.9264	4-5
84. **Standing-height Shop-style Workbenches	4.52	-0.07	5	1.0159	4-5
85. **Stools	4.39	-0.04	5	1.0525	4-5
86. **Storage Lockers for Projects	4.52	-0.07	5	0.9722	4-5
87. **Tool Storage Cabinet	5.13	-0.04	5	0.7404	5-6
88. **Wall Mounted Tool Cabinets	4.70	0.00	5	0.9972	5-5
Separate Classroom/Lecture Space					
89. Book Storage Shelf	4.00	-0.08	4.5	1.4938	4-5
90. **Bulletin Board	4.43	-0.04	5	1.5535	5-5.75
91. Durable Theater Seating with Writing Surface	3.05	-0.11	3	1.8988	1.25-5
92. Lockable Storage Cabinets	3.39	-0.17	4	1.3058	4-5
93. **Marker Board	4.48	-0.10	5	1.3484	5-6
94. Multimedia Cabinet	3.95	-0.14	4.5	1.4666	5-5
95. **Printer Table	3.95	-0.10	5	1.4666	4-5
96. **Projection screen	4.55	-0.09	5	1.4800	5-6
97. Standard Student Desks	3.45	-0.08	4	1.8570	2-5
98. **Teacher Workstation/Desk	4.59	-0.05	5	1.3361	5-5.75
Additional Instructional Furnishings					
99. Built-in Countertops for Video Room	3.30	0.01	4	1.3652	2-4

Probe Question Four: How should each support space be furnished for 28 students and 1 instructor?

ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
Instructor Office Space					
100. **Book Storage Shelves	4.48	-0.14	5	1.4349	4-5
101. **Book/Multimedia Storage Cabinet	4.57	-0.04	5	1.0942	5-5
102. Built-in Counter Workspace	3.33	-0.07	4	1.1684	3-4
103. **Instructor Desk	5.05	-0.04	5	1.3265	5-6
104. Lockable Filing Cabinet	4.81	-0.05	5	1.2954	4-6
105. **Lockable Storage Cabinet	4.81	-0.11	5	1.3316	5-6
General Storage					
106. **Braced Metal Storage Shelving	5.00	0.05	5	0.7559	5-5
107. **Built-in Storage Shelving	4.48	0.00	5	0.8518	4-5
108. Hanging Hooks	3.95	-0.02	4	0.9500	3-5
109. **Large Clear Plastic Bins	4.90	0.01	5	0.8109	4-5
110. **Lockable Storage Cabinet	4.95	0.02	5	0.5754	5-5

111.	Wire Rack Storage Shelving	4.19	-0.01	4	1.0057	4-5
	Project Storage					
112.	Cage-type Access Project Storage	3.90	0.06	4	1.0191	4-5
113.	Portable Storage Cabinets	3.76	-0.07	4	0.8677	4-4
114.	Portable Wire Shelving Carts with Plastic Organizers	3.95	-0.02	4	1.1329	3-4
115.	**Shelving Units	4.85	-0.04	5	0.4770	5-5
116.	Wire Rack Storage Shelving	4.19	0.04	4	0.7940	4-5
	Equipment/Tool Storage					
117.	Built-in Storage Shelving	4.29	-0.09	4	0.8248	4-5
118.	Braced Metal Storage Shelving	4.52	0.05	5	0.7315	4-5
119.	**Lockable Storage Cabinet	5.24	0.00	5	0.6835	5-6
120.	Wire Rack Storage Shelving	3.45	0.17	4	0.9989	4-5
	Various Support Space Furnishings					
121.	Technology Student Association (TSA) Book/Multimedia Storage	2.80	-0.17	2.50	1.2490	2-4
122.	TSA Book Storage Shelving	2.90	-0.19	3	1.2610	2-4
123.	TSA Built-in Counter Workspace	2.35	-0.30	2	1.1522	2-4
124.	TSA Lockable Filing Cabinet	3.10	-0.16	3	1.4107	2-4
125.	(TSA) Lockable Storage Cabinet	3.20	-.015	3	1.4353	2-4.25
126.	(TSA) Officer Desk	2.80	-0.24	2.50	1.2490	2-4
127.	Video Room Built-in Countertop Workspace	2.55	-0.18	2	1.2031	2-3

Probe Question Five: What types of facility safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
128.	**Clear Sightlines within Space for Student Supervision	5.67	-0.03	6	0.4714	5-6
129.	**Direct Exhaust Vents	5.05	0.04	5	0.8438	5-6
130.	**Emergency Shut Off Switch	5.33	-0.04	6	0.8909	5-6
131.	**Evacuation Plans	5.71	-0.01	6	0.4518	5-6
132.	**Eye Wash Station	5.33	-0.01	6	0.8357	5-6
133.	**Fire Extinguishers	5.33	-0.06	6	0.8357	5-6
134.	**Fire Resistant Trash Can	5.33	0.01	6	0.8357	5-6
135.	**Flammable Storage Cabinet (Vented)	5.29	0.04	5	0.9331	5-6
136.	**General Safety Rules Posted	5.81	0.01	6	0.3927	6-6
137.	**Glass Sterilizing/Storage Cabinet	4.90	0.06	5	0.9434	4-6

138.	**Hazardous Chemical Storage Cabinet (Vented)	5.14	0.05	6	1.1249	5-6
139.	High-Impact Block Walls	4.86	0.02	5	1.1249	4-6
140.	**High-Impact Safety Glass in Divided Areas for Supervision	4.95	0.01	5	0.9989	5-6
141.	**Kill Switches for Large Equipment	5.52	0.00	6	0.9060	5-6
142.	**Machine Exhaust System	5.52	0.11	6	0.9060	5-6
143.	**Machine Specific Safety Rules Posted at Each Machine	5.52	0.05	6	0.9060	5-6
144.	**Mounted First Aid Kit	5.67	-0.02	6	0.5634	5-6
145.	**Paper Towel Rack	5.05	-0.02	5	0.6529	5-5
146.	**Quick Communication to Main Office	5.57	-0.03	6	0.5832	5-6
147.	**Regulated Air Connection	5.19	0.00	5	0.6633	5-6
148.	Restroom with Emergency Chemical Shower w/Floor Drain	3.90	-0.02	4	1.1914	3-5
149.	**Safety Signs	5.62	-0.02	6	0.4856	5-6
150.	Sealed Concrete Floors	4.81	0.02	5	1.0519	4-6
151.	**Shields/Guards on Machines	5.57	-0.01	6	0.9035	5-6
152.	**Sink with Soap Dispenser	5.19	-0.02	5	0.8518	5-6
153.	**VCT in Production and Storage Areas to Minimize Trip Hazards	4.57	0.06	5	0.8492	4-5
154.	**Well Marked Safety Zone Areas	5.38	0.04	6	0.9500	5-6

Probe Question Six: What types of personal safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
155.	Aprons	3.71	-0.04	4	1.0754	3-4
156.	**Dust Masks	4.57	-0.02	5	0.9035	4-5
157.	**Ear Protection	4.57	0.00	5	0.9035	4-5
158.	**Eye Protection (Safety Glasses/Goggles)	5.52	0.00	6	0.9060	5-6
159.	**Face Shields	4.67	0.07	5	0.9428	4-5
160.	Gloves	4.19	0.07	4	1.1389	4-5
161.	Hard Hat	3.19	0.00	3	0.9060	3-4
162.	Protective Clothing	3.48	-0.02	4	0.8518	3-4
163.	Respirators with Disposable Filters	3.67	-0.03	4	0.9920	3-4
164.	**Safety Glasses	5.48	-0.03	6	0.9060	5-6

165.	Welding Safety Equipment	4.55	0.01	5	1.1608	4-5.25

Probe Question Seven: What types of hand tools are necessary?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
166.	**Adjustable Wrenches	5.15	0.01	5	0.5723	5-5.25
167.	**Ball Peen Hammer	4.75	-0.02	5	0.9937	4-5
168.	**Bar Clamps	4.65	0.00	5	0.9631	5-5
169.	**Bench Brushes	5.00	0.05	5	0.6325	5-5
170.	**Bolt Cutters	4.95	0.05	5	0.7399	4-5
171.	C-Clamps	4.30	0.08	4	0.9539	5-6
172.	**Center Punch	5.10	0.01	5	0.7000	4-5
173.	**Claw Hammer	4.65	0.01	5	0.9097	4-5
174.	Cold Chisels	4.35	0.00	4	1.0137	4.5-5
175.	**Coping Saw	4.79	0.01	5	0.8932	5-5
176.	**Crescent Wrench Set	5.05	0.01	5	0.5895	4-5
177.	**Desoldering Iron	4.60	0.00	5	0.9695	4-5
178.	**Divider	4.70	0.06	5	0.9000	4-5
179.	**Electronics Vise	4.55	0.03	5	1.0235	4-5
180.	**English Allen Wrenches	4.90	0.00	5	0.7000	5-5
181.	**English Wrenches	4.90	-0.02	5	0.7681	4.75-5
182.	Etching System	3.95	0.19	4	1.1169	3-5
183.	File Card	4.20	0.06	4	1.0296	3.75-5
184.	**Flat Head Screwdrivers	5.15	0.02	5	0.5723	5-5.25
185.	**Hack Saw	5.10	-0.02	5	0.5385	5-5
186.	**Hand Drill	5.20	0.02	5	0.6000	5-6
187.	Hand Seamer	3.75	-0.05	4	1.0897	3-4
188.	**Hex Wrenches	4.85	-0.02	5	0.7263	4.75-5
189.	**Hot Glue Guns	5.20	0.03	5	0.6782	5-6
190.	**Level	4.80	-0.02	5	0.6782	4-5
191.	**Magnets	4.80	0.11	5	0.6782	4-5
192.	**Metal Files	4.90	-0.01	5	0.6245	4.75-5
193.	**Metal Punch	4.60	-0.03	5	0.9695	4-5
194.	**Metric Allen Wrenches	4.95	-0.04	5	0.7399	5-5
195.	**Metric Wrenches	5.00	-0.02	5	0.7071	5-5
196.	**Nail Set	4.70	0.01	5	0.8426	4-5
197.	**Phillips Screwdrivers	5.15	-0.01	5	0.5723	5-5.25
198.	**Plastic Mallet	4.80	0.01	5	0.8124	4.75-5
199.	**Pliers	5.15	-0.02	5	0.5723	5-5.25
200.	**Pop Rivet Gun	4.65	0.01	5	0.9631	4-5
201.	**Rubber Mallet	5.05	0.00	5	0.7399	5-5.25
202.	**Sanding Blocks	4.60	-0.06	5	1.0198	4-5
203.	**Scissors	5.35	0.04	5	0.5723	5-6
204.	Scratch Awl	4.47	-0.01	4	0.9931	4-5
205.	Scribes	4.40	-0.05	4	1.0198	4-5

206.	**Socket Set	5.10	-0.03	5	0.7681	5-6
207.	**Soldering Equipment	5.00	-0.01	5	0.8944	5-5.25
208.	**Spring Clamps	4.85	-0.03	5	0.8529	5-5
209.	**Staple Gun	4.90	0.01	5	0.7000	5-5
210.	**Straight Edges	5.30	0.00	5	0.5568	5-6
211.	**Tin Snips	4.80	-0.01	5	0.8718	4.75-5
212.	Torque Wrenches	4.60	-0.05	5	1.2000	4-5.25
213.	**Triangles	5.00	0.02	5	0.6325	5-5
214.	**Try Square	4.85	0.00	5	0.6538	4-5
215.	**T-Squares	4.80	0.00	5	0.8718	4-5
216.	**Tweezers	4.55	-0.05	5	0.9734	4-5
217.	**Twist Drills	4.75	-0.01	5	0.9937	4-5
218.	**Utility Knives	5.25	0.02	5	0.6225	5-6
219.	**Wire Snips	5.05	0.01	5	0.8646	5-5.25
220.	**Wire Strippers	5.00	-0.01	5	0.7746	5-5.25
221.	**Wood Chisels	4.50	-0.03	5	1.0724	4-5
222.	**Wood Files	4.60	-0.03	5	0.8602	4-5
223.	**Workbench Vises	5.00	0.02	5	0.7071	5-5
224.	**X-acto Knives	5.26	0.06	5	0.6359	5-6

Probe Question Eight: What types of hand held power tools are necessary?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
225.	Assorted Air Tools	4.25	0.01	4	0.8292	4-5
226.	**Belt Sander	4.75	0.00	5	0.7665	5-5
227.	Buffer	4.05	0.05	4	0.9206	3-5
228.	**Corded Hand Drill	4.75	0.04	5	0.7665	4.75-5
229.	**Cordless Hand Drill	5.00	-0.05	5	0.7746	5-5.25
230.	**Dremel Tool	5.00	0.03	5	0.7746	5-5.25
231.	Electric Chisels	3.65	0.13	3.5	1.1079	3-4.25
232.	**Grinder- with Sandpaper	4.52	0.03	5	0.8518	4-5
233.	**Grinder- with Wheel	4.47	-0.06	5	0.9386	4-5
234.	**Hot Air Gun	4.70	0.15	5	0.9000	4-5
235.	**Hot Wire Cutter	4.70	0.06	5	0.9000	4-5
236.	**Jig Saw	4.95	-0.01	5	0.8047	5-5
237.	Laminate Trimmer Bits	4.40	0.14	4.5	0.8602	4-5
238.	Orbital Sanders	4.40	0.00	4.5	0.8602	4-5
239.	Palm Sander	4.25	-0.07	4	0.7665	4-5
240.	Plastic Heat Strip	4.32	0.02	4	0.9207	4-5
241.	Plastics Welder	4.25	0.04	4	0.7665	4-5
242.	Pneumatic Nail Gun	3.70	0.01	4	1.2689	2.75-5
243.	Portaband (for metal Cutting)	4.00	-0.06	4	1.0488	4-5
244.	Rotary Cutter	3.85	-0.03	4	1.0137	3-5
245.	**Router	4.47	0.04	5	0.7517	4-5
246.	**Router Bits	4.47	0.04	5	0.7517	4-5

247.	Saws All	4.30	0.00	4.5	0.8426	4-5
248.	Sheet Metal Shear	4.25	-0.01	4.5	0.9421	4-5
249.	**Skill Saw	4.50	-0.04	5	0.6009	4-5
250.	**Solder Pens	4.58	0.01	5	0.7480	4-5
251.	**Solders Gun	4.68	-0.02	5	0.7293	5-5
252.	**Strip Heater	4.40	0.00	5	0.800	4-5
253.	Wafer Doweling Tool	3.40	-0.01	3	1.0198	3-4

Probe Question Nine: What types of material processing equipment are necessary?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
254.	**3D Printer	4.40	-0.05	5	1.1136	4-5
255.	**Air Compressor	4.65	-0.03	5	0.9097	4-5
256.	Autonomous Robot	4.30	0.05	4	1.1000	4-5
257.	**Band Saw	4.95	0.02	5	0.9206	5-5.25
258.	CIM CELL with Robotic Arm, and Conveyor Belt	4.20	-0.02	4	1.1225	4-5
259.	**CNC Lathe	4.45	-0.02	5	1.1169	4-5
260.	**CNC Mill	4.75	0.05	5	1.0897	5-5
261.	**CNC Router	4.45	-0.01	5	1.1169	4-5
262.	**Combo Belt/Disc Sander	4.75	0.04	5	0.8874	4-5
263.	**Drill Press	5.10	-0.02	5	0.9434	5-6
264.	Foam Cutter	4.45	-0.07	4.5	0.8646	4-5
265.	**Grinder/Wire Wheel Combo	4.70	0.06	5	0.8426	4-5
266.	Jointer	4.10	0.00	4	1.1790	3-5
267.	Laser Engraver	4.10	0.02	4	1.1790	3-5
268.	Metal Band Saw	4.25	-0.08	4	1.0897	4-5
269.	Metal Brake	3.90	-0.06	4	0.9434	3-5
270.	Metal Foot Shear	3.70	-0.06	4	0.9539	3-4
271.	Metal Lathe	3.40	-0.15	4	1.1136	2.75-4
272.	Metal Slip Rollers	3.55	-0.06	3.5	0.9734	3-4
273.	MIG Welder	3.80	-0.04	4	0.9274	3-4.25
274.	Oxy-Acetylene Unit	3.75	-0.02	4	0.8874	3-4
275.	Planer	3.80	0.02	4	1.0770	3-5
276.	Plastic Injection Molder	4.00	-0.02	4	0.9487	4-5
277.	Plastic Vacuum Forming Machine	4.05	-0.02	4	0.9734	4-5
278.	Plastics Machine (multi-purpose)	4.05	-0.04	4	0.9734	4-5
279.	Radial Arm Saw	4.20	0.03	4	0.9274	4-5
280.	**Scroll Saw	4.50	0.01	5	0.5916	4-5
281.	Sheet Metal Tools	4.30	-0.04	4.5	1.0050	4-5
282.	Sliding Compound Miter	4.40	0.00	4	0.9695	4-5
283.	Small MIG/Arc Welder Combo	4.05	0.08	4	1.0712	4-5

284.	Spindle Sander	3.90	0.11	4	1.0909	3.4.25
285.	Spot Welder	3.90	0.02	4	1.2610	3-5
286.	**Table Saw	4.65	0.02	5	0.7921	4-5
287.	**Table Top Band Saw	4.79	0.02	5	0.8932	4.5-5
288.	**Table Top Drill Press	4.95	0.03	5	0.8047	4.75-5.25
289.	Table Top Table Saw	4.45	-0.04	4.5	1.1169	4-5
290.	Thermo Fax Machine	3.10	-.012	3	1.1790	2-5
291.	Thermo former	3.60	-0.03	4	1.2000	3-5
292.	TIG Welder	3.21	0.01	3	1.1956	2.5-4
293.	Vinyl Sign Machine	3.50	-0.03	3.5	1.3964	2-4.25
294.	Wood Lathe	2.95	-0.08	3	1.0235	2-3.25

Probe Question Ten: What types of computer software are necessary?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
295.	**2D CAD	4.57	0.07	5	1.0034	4-5
296.	**3D Modeling/Design and Analytical	5.38	0.00	6	0.7222	5-6
297.	**Animation	4.90	0.04	5	0.6835	5-5
298.	**Architectural Design	5.10	0.04	5	0.8888	4.75-6
299.	**Civil Design	4.52	0.09	5	0.6633	4-5
300.	**Classroom Management and Supervision	4.76	0.03	5	1.1508	4-6
301.	**Clip Art	4.48	0.01	5	0.9060	4-5
302.	**Data Base	4.43	-0.06	5	0.9035	4-5
303.	**Desktop Publishing	4.90	0.00	5	0.5385	5-5
304.	Dictionary	3.81	0.01	4	0.7940	3-4
305.	**Electronic Circuit Design	4.67	-0.05	5	0.7766	4-5
306.	**Electronics Training and Simulation	4.48	-0.05	5	0.9571	4-5
307.	**Engineering Training	4.67	-0.07	5	0.9428	5-5
308.	**Finite Element Modeling	4.71	0.08	5	0.8248	4-5
309.	Gaming Development	3.76	-0.04	4	1.0648	3-4
310.	**Internet Browser	5.48	-0.02	6	0.5871	5-6
311.	MathCAD	4.29	0.01	4	0.9331	4-5
312.	**Mechanical Workbench	4.50	0.03	5	0.8062	4-5
313.	**Multimedia and Presentation Graphics	5.19	-0.01	5	0.7940	5-6
314.	**Multimedia Generation and Podcast	4.70	0.04	5	0.9000	4-5
315.	**Parallax Basic Stamp PLC Programming	4.37	0.03	5	0.8085	4-5
316.	**PC Control	4.50	-0.02	5	0.8062	4-5

317.	Sign or Banner Making	3.65	-0.08	3.5	1.1948	3-5
318.	**Software for Programming Robots	4.86	-0.02	5	1.1249	5-5
319.	**Spread Sheet	5.19	-0.01	5	0.5871	5-6
320.	**VEX Easy C PLC Programming	4.68	0.02	5	1.1264	4.5-5
321.	Video Editing	4.00	-0.03	4	1.2724	4-5
322.	**Web-Design	4.43	0.02	5	0.9548	4-5
323.	**WestPoint Bridge Builder	4.71	-0.02	5	0.9331	4-5
324.	**Word Processing	5.48	-0.01	6	0.5871	5-6

Probe Question Eleven: What types of audiovisual equipment are necessary?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
325.	Cable TV Access	4.43	0.05	4	1.1369	4-5
326.	Computer Display-Touch Sensor	4.05	0.04	4	0.9989	4-5
327.	**Computer Projection System (LCD Projector and Projection Screen)	5.14	-0.05	5	0.8883	5-6
328.	Convex Mirrors for Student Supervision	3.62	-0.08	4	1.3619	3-5
329.	**Digital Camcorder	4.81	-0.04	5	0.7940	5-5
330.	**Digital Camera	5.05	0.04	5	0.5754	5-5
331.	Document Camera	4.00	0.02	4	1.0000	3-5
332.	**DVD Player	4.62	-0.04	5	1.0900	4-5
333.	**Interactive or Smart Board	4.33	-0.07	5	1.0838	4-5
334.	Interactive Tablet	4.20	-0.03	4.5	1.0296	3-5
335.	**Scanner	4.95	0.00	5	0.5895	5-5
336.	Scrolling Message Board	3.05	-0.13	3	1.3219	2-4
337.	Stereo/CD player and Speakers with Surround-sound	3.76	-0.04	4	1.2307	3-5
338.	TV Set	4.05	-0.03	4	1.3619	4-5
339.	VCR	3.14	-0.03	3	1.2454	2-4
340.	**VCR/DVD Combo Player-Recorder	4.76	0.02	5	0.7499	4-5
341.	**Web Access	5.57	0.02	6	0.6598	5-6
342.	**Web Camera	4.57	-0.01	5	1.1780	4-5
343.	**Wireless Mouse	4.33	-0.09	5	1.2472	4-5
344.	**Wireless Pointer	4.40	0.02	5	1.1576	4-5
345.	Wireless Mic &Speakers	4.14	-0.03	4	1.2454	4-5

Probe Question Twelve: What types of measuring and testing devices are necessary?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
346.	**Adjustable Triangles	4.65	0.01	5	0.6538	4-5
347.	Altimeter Gun	4.20	-0.02	4	1.0296	4-5
348.	**Architects Scale	4.90	-0.02	5	0.9434	4.75-5.25
349.	Computer Interfaced Materials/Structural Tester	4.65	0.18	4	1.0137	4-5
350.	**Dial Calipers	4.95	-0.02	5	0.7591	5-5
351.	**Drafting Tools	4.70	0.01	5	0.0539	4-5
352.	**Engineering Scale	5.05	-0.02	5	0.9206	5-6
353.	**Fast Read Thermometers	4.65	0.00	5	0.7921	4-5
354.	**Framing Square	4.50	0.01	5	0.9747	4-5
355.	GPS Tracking Device	4.15	-0.02	4	1.1079	4-5
356.	**Graduated Metal T-Squares	4.58	0.08	5	0.6740	4-5
357.	Hydrometer	4.10	0.00	4	0.8888	4-5
358.	Large Package Shipping Scale (600lbs)	3.95	0.11	4	1.1169	3-5
359.	**Laser Level	4.55	0.05	5	0.9206	4-5
360.	**Laser Tape Measure	4.40	0.03	5	0.9165	4-5
361.	**Level	4.74	0.02	5	0.8487	4-5
362.	Light Guns	4.15	0.05	4	0.9097	4-5
363.	**Measuring Tape	5.16	-0.02	5	0.7443	5-6
364.	**Metal Rulers	5.16	0.01	5	0.7443	5-6
365.	**Meter Sticks	5.00	-0.05	5	0.7071	5-5
366.	**Metric Rulers	5.10	-0.03	5	0.6245	5-5.25
367.	**Micrometers	5.05	-0.04	5	0.8047	5-6
368.	**Multi-Meters	5.00	-0.04	5	0.7746	5-5.25
369.	**Oscilloscopes	4.65	0.02	5	0.7263	4-5
370.	PH Sensors	4.00	-0.03	4	0.9487	3.75-5
371.	Postage Scale	3.90	-0.06	4	1.0909	4-5
372.	**Power Supplies	5.00	0.00	5	0.7746	5-5.25
373.	**Pressure Sensors	4.65	0.01	5	1.0137	4-5
374.	Printer Scale	4.10	-0.02	4	0.9434	4-5
375.	**Protractors	4.90	-0.02	5	0.6245	4.75-5
376.	Speed Square	4.15	0.06	4	0.9631	4-5
377.	**Spring Scales	4.75	0.03	5	0.8874	4-5
378.	**Stopwatches	5.00	-0.01	5	0.5477	5-5
379.	**Strain/Stress Gage	4.85	-0.03	5	0.7263	4-5
380.	**Temperature Sensors	4.70	-0.05	5	0.9539	4-5
381.	**Transit and Fulcrum	4.55	0.02	5	0.9206	4-5
382.	Triple Balance Beam with Weights	4.80	0.04	5	0.9798	4-5.25
383.	**Wind Tunnel	4.65	0.05	5	0.9631	4-5

384.	Wood Rulers	3.80	-0.06	4	1.2083	3-5

Probe Question Thirteen: How many computers (and computer related equipment) are necessary?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
			Student Computers			
385.	(4) Student Laptops Dedicated for TSA Conference Competitions	4.45	0.01	4.5	2.0118	3-5
386.	(6) Student Computers	1.48	-0.24	1	0.7940	1-2
387.	(7) Computers	1.57	-0.25	1	0.7911	1-2
388.	(15) Student Computers	2.48	-0.21	2	1.3316	1-3
389.	**(1) Computer Per Student for a Total of (28) Student Computers	5.50	0.08	6	0.5916	5-6
390.	(30) Student Computers	4.32	0.08	4.5	1.1032	4-5
391.	(45) Student Computers	2.00	000	2	1.3093	1-2
392.	**(1) Dedicated Computer for Each CNC Machine (Robot, Mill, Lathe, and Laser Engraver) in Addition to the Student Computers	4.95	0.06	5	1.0500	5-6
			Instructor Computers			
393.	**(1) Instructor Computer	5.29	-0.03	5	0.6999	5-6
394.	**(1) Instructor Laptop	4.60	-0.15	5	1.0198	4-5
395.	(2) Instructor Computers	5.05	0.18	5	1.5163	4-6
396.	**(1) High Powered Demonstration Computer	4.86	-0.01	5	0.7737	4-5
			Printers			
397.	**(1) Black & White Laser Printer	5.15	0.00	5	0.7263	5-6
398.	**(1) Color Laser Printer	5.14	-0.04	5	0.7737	5-6
399.	**(1) Large Format CAD Printer/Plotter	5.10	0.00	5	0.8888	5-6
400.	(1-4) Inkjet Printer	3.86	-0.02	4	1.0994	3-5
401.	**(1-2) Scanner	5.19	0.01	5	0.8518	5-6
402.	(1) Fax	3.33	-0.05	3	0.9920	3-4
			General Lab			
403.	**(1) Classroom Phone	5.57	0.05	6	0.9828	5-6
404.	**(1-2) Dedicated Phone Line	4.95	0.08	5	1.3299	5-6
405.	(1-2) Video Editing Stations	3.60	-0.09	4	1.3619	3-5
406.	**(1-2) Digital Still Cameras	5.19	0.01	5	0.7737	5-6
407.	**(1-2) Camcorders	4.86	-0.03	5	0.8729	4-5

408.	**Networked Lab with Internet Connection	5.57	-0.02	6	0.5634	5-6

Probe Question Fourteen: What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, or other engineering related equipment, if any, are necessary?

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
409.	Alternative Energy Systems Kits and Trainers	4.05	-0.01	4.5	1.2835	4-5
410.	**Automated Manufacturing Equipment	4.25	0.00	5	1.4790	4-5
411.	Civil Engineering Trainer Kit	3.65	-0.03	4	1.2359	3-4.25
412.	Electrical Motor Kits	4.95	-0.02	4	1.2835	4-5
413.	Fischer Tech Interfacing	3.35	-0.08	3.5	1.2757	3-4
414.	Hydraulics Trainer	3.65	-0.02	4	1.3143	3-5
415.	Mechanisms Trainer	3.85	0.02	4	1.2359	3.75-5
416.	No Packaged Kits or Trainers are Necessary	3.45	0.07	3	1.6271	2-5
417.	Pneumatics Trainer	3.60	-0.04	4	1.3191	3-5
418.	Precision Measurement Trainer	3.95	0.01	4	1.2440	3.75-5
419.	Sensors and Transducers Kit	4.10	-0.04	4.5	1.3379	4-5
420.	**Variety of Electronics Basic Electricity Training Kits (Gibson Tech, Tronix, etc.)	4.45	-0.04	5	1.2440	4-5
421.	**Variety of Robotics Trainers (VEX, Lego Mindstorm, etc.)	4.65	-0.01	5	1.2359	4-5

Probe Question Fifteen: List any other item you feel is necessary for teaching engineering design concepts to high school students.

	ITEM	Mean	Δ Mean (%)	Median	SD	IRQ
422.	**3 Hole Punch	5.05	0.03	5	0.8109	4-5
423.	**Clear Tape	5.10	-0.01	5	0.6389	5-6
424.	**Collaboration with Math and Science Teachers	5.55	0.00	6	06633	5-6
425.	**Colored Markers	5.10	0.00	5	0.7499	5-6
426.	**Colored Pencils	4.95	0.03	5	0.9060	4-5
427.	**Computer Paper	5.25	-0.02	5	0.5754	5-6
428.	**Construction Paper	5.00	0.05	5	1.1014	4-6
429.	**Dry Erase Markers	5.25	-0.03	5	0.4949	5-6
430.	**Engineering Design Notebooks	5.35	-0.03	6	0.5871	5-6

431.	**Glue	5.25	0.01	5	0.7315	5-6
432.	**Masking Tape	5.26	0.01	5	0.6633	5-6
433.	**Office Supplies	5.35	-0.02	5	0.4975	5-6
434.	**Paper Cutter	5.20	0.00	5	0.7315	5-6
435.	**Partnerships with Local Manufacturers, Business, Engineering Firms, etc	5.55	0.00	6	0.4994	5-6
436.	Play Dough	3.90	0.12	4	1.4349	2-4
437.	**Reverse Engineering	5.00	0.03	5	0.9404	4-6
438.	**Stapler	5.25	0.00	5	0.6835	5-6
439.	**State Approved Curriculum	4.95	0.04	5	1.3768	4-6
440.	Tissue Paper	4.45	-0.01	4.5	0.9060	4-5
441.	Turn Key Project Lead the Way Curriculum	3.21	-0.19	4	1.9875	1-6
442.	**Waste Paper Baskets	5.25	-0.19	5	1.1358	5-6
443.	**Water Fountain	5.10	0.19	5	1.1358	5-6
444.	**New Item-Recycle Bin	5.32	N/A	5	0.6531	5-6

Round Three Additional Comments

As in Round 2, participants were encouraged to provide an explanation of their answer on any particular item. Table 4.8 contains the comments given by participants.

Table 4.8

Round Three Additional Comments

Number	Participant Comment
Probe Question 1	
Combination Computer/Lecture	
1.	About 1250 square feet should be adequate for lecture/computer/presentation area.
2.	The students should have some space to use computers, listen to lecture and give presentations-- but it does not need to be distinct from other spaces.
	Standard classroom is typically 600 to 800 sq ft ideal would be 1000 for incorporation of some computers in a typical classroom. Raised or stepped seating can take place in 400 sq ft. A lot depends on the variables you deal with when constructing a classroom/laboratory environment. Money is also a major factor. Another consideration is student numbers and if you have a large number you may lose a separate classroom versus one that is an integral part of the laboratory.
One Room Multi-Purpose	
1.	Multipurpose does not include construction, storage, CAD/computer
2.	Essentially, I believe that you would only need this one room. I think that engineering design *could* be taught in any sized room. A larger space would be nice, even preferable, but not critical and necessary.
3.	This is just a large classroom. Multi-purpose lab should be 2700 sq ft min to 3600 sq ft

Flexible Workspace

1. I would see this as one use of the multipurpose lab; you would need to make sure that your multipurpose lab is set up in such a way that there is room for project staging, materials testing, teamwork, etc.

Prototyping

1. Again, I think that you would need just the one multipurpose space. You would need to make sure that one of the things that students could do in this space was prototyping.

Separate Classroom

1. Contained within the combination presentation, lecture and CAD/Computer Lab
2. Classroom/computer lab should be together
3. A separate classroom that is adjacent to the lab would only be beneficial if it could also be used as IU for other curriculum (700 sf).
4. Not needed if the other spaces are included.

Various Spaces

1. The testing lab and video production room would be nice additions, but not necessary and/or critical for learning engineering design. Some part of the multipurpose room should facilitate research/store resources.
2. If it is 100 sq. feet dedicated to testing only, that is too small. But if 100 sq. ft. additional for testing onto other spaces, then that might work out.

Probe Question 2

Instructor Office

1. Nice to have, but not necessary/critical.

General Storage

1. None

Project Storage

1. Would not be necessary to have this in addition to general storage, but project storage likely should be incorporated in general storage

Equipment and Tool

1. I see this as being a part of the general storage, but not in addition

Various Spaces

1. Nice, but not necessary; server closet may vary by school (existing network setup).

Probe Question 3

1. Flexibility is Key.
2. There is no need for a separate classroom space
3. You can do video right in the CAD lab...Movie Maker and a camera. Video space is not necessary

Probe Question 4

1. Teacher office is not needed.
2. Caster on storage rack is useful.
3. I think project storage really depends on the lab design and storage options available
4. TSA does not need its own room

Probe Question 5

1. None.

Probe Question 6

1. None

Probe Question 7

1. None.

Probe Question 8

1. None.

Probe Question 9

1. Lathes should be CNC for wood and metal.
2. I don't picture the engineering lab needing large metalworking or woodworking equipment except for the drill press and band saw. If there were a special project that needed, say, heavy welding, that could be sent out to a supporting company/industry friend.

Probe Question 10

1. None

Probe Question 11

1. None

Probe Question 12

1. None

Probe Question 13

1. One computer per student plus proprietary computers for some pieces of equipment would be nice
2. The more computers you have the more students they put in one section - keep it at 28. Most school calculate class size by average - that means you can have 6 one period and 40 the next.
3. I like the idea of 4 laptops, these computers can be taken to conferences.
4. The laser printers are needed for any type of desktop publishing projects, but the plotters can be inkjet
5. If you have network color and b/w printers, you might need one inkjet for TSA conferences.
6. Video room should be used for TSA and program marketing. Not for newsroom purposes
7. Editing software can be on CAD computers

Probe Question 14

1. Some of the electronics training kits optimize the time it takes to instruct students about basics electronics. With this basic knowledge they will be able to move to "engineering" their own circuits for a specific purposes.

Probe Question 15

1. None

Summary

The Delphi technique was used for this research with the goal of adding to the growing body of literature for the inclusion of engineering design in secondary technology education courses. This study relied on three rounds of survey to elicit the responses of persons considered experts in the field of technology education. Participants accessed the survey instrument for each round electronically via the internet using SurveyMonkey.com™, a web-based data collection website. A total of 442 unique items were identified during Round 1 in answer to 15 open-ended probe questions. In the subsequent Round 2, participants suggested an addition of 2 items for a total of 444 unique responses. In Rounds 2 and 3, participants indicated their responses on 6-point Likert-type scales where they were given a chance to revise their own responses in light of the group response to the same items, and add comments on any response they felt they needed to explain. In Round 3, the statistical results from the second round survey were reported to participants.

The inter-quartile range and the inter-round mean score change (Δ Mean) were two major indices noted for each item in this study. The inter-quartile range indicated the degree of group consensus, and the inter-round mean score change was an indication of item stability. After all rounds were completed, seventy-five percent of the items (335/444) had achieved an IQR of ≤1. A total of 442 of the 444 items had measurable inter-round mean scores. The additional items were suggested in Round 2, and were thus only included as survey items for one round, which was Round 3.

It was decided to identify items as very important for the purposes of this study only if they met 3 specific criteria:

1. An inter-round mean Δ of <15% (indicating stability)
2. A median score of 5 or 6 (indicating a strong level of agreement among participants)
3. An IQR range of $\leq$ 1 (indicating consensus)

In total 268 items met these standards. Though 14 furniture items that were from instructional spaces (e.g., furniture from the multipurpose room, instructor's office, and project storage room) found not to be significant were later dropped from the significant list. With the reduction of furnishings 254 items met these standards and are identified in Table 4.7 with double asterisk (**) symbols. These 254 items became the basis for the conclusions drawn from this Delphi process, and the recommendations made for the field of technology education. Table 4.9 reports the ranking of each individual item reported within the designated probe question. A 'T' reported alongside the ranking for any item indicates that there was a tie between items identified for that question. For further clarification, Table 4.9 represents only those items which qualified as the highest category of inclusion for this study and excluded all other items. These items are presented in order of ranking and are linked to the designated probe questions.

Table 4.9

Mean Score Ranking of Items Identified by Delphi Process

Probe Question One: What types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?

ITEM	Mean Score	Rank (Question 1 by Area)
Combination Computer, Lecture, Presentation Area		
(1000 to 1500 Square Foot) Combination Computer Lecture, Presentation Area	4.87	1
Flexible Workspace		
New Item (1200-1800) Square Foot Space	4.41	1
Prototyping/Material Processing Area		
(1000 to 1300 Square Foot) Prototyping/Material Processing	4.35	T1
(2000 to 2300 Square Foot) Prototyping/Material Processing	4.35	T1
Additional Instructional Spaces		
(200 Square Foot) Research/Resource Area	4.39	1
(250 Square Foot) CNC/CIM/Rapid Prototyping Area	4.30	2

Probe Question Two: What types of support spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?

ITEM	Mean	Rank (Question 2 by Area)
General Storage/Supply Room		
(200 to 250 Square Foot) General Storage/Supply Room	4.68	1
Equipment/Tool Storage Room		
(100 to 150 Square Foot) Equipment/Tool Storage Room	4.70	1

Probe Question Three: How should each instructional space be furnished for 28 students and 1 instructor?

ITEM	Mean	Rank (Question 3 by Area)
Combination Computer, Lecture, Presentation Area		
Instructor Work Station/Desk	5.36	1
Lockable Storage Cabinet	5.32	2
Projection Screen	5.26	3
Bulletin Board	5.22	4
Marker Board	5.17	5
Bookshelf Storage Case	5.04	T6
File Cabinet	5.04	T6
Combination CAD/Drafting Student Workstations	4.91	7
Printer Table	4.86	8
Computer Style Chairs	4.52	9

Display Cabinet with Shelves	4.43	T10
Rolling Adjustable Chairs	4.43	T10
Multimedia Cabinet	4.48	11
Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work		
Lockable Storage/Supply Cabinets	5.17	1
Storage Cabinet	5.04	2
Teacher Command Station	4.82	3
Prototype and Testing Stations with Adjustable Stool	4.74	4
Printer Table	4.70	5
Adjustable Stools	4.65	T6
Standard-height Student Worktables	4.65	T6
Activity Storage Cabinet w/Tote Trays	4.61	7
Mobile Material and Activity Cart	4.43	8
Prototyping/Material Processing		
Tool Storage Cabinet	5.13	1
Lockable Storage/Supply Cabinets	5.09	2
Large Sink	4.78	3
Wall-mounted Tool Cabinets	4.70	4
Activity Storage Cabinets w/Tote Trays	4.65	5
Demonstration Table	4.55	6
Standing-height Shop-style Workbenches	4.52	T7
Storage Lockers for Student Projects	4.52	T7
Mobile Material and Activity Cart	4.48	8
Stools	4.39	9

Probe Question Four: How should each support space be furnished for 28 students and 1 instructor?

ITEM	Mean	Rank (Question 4 by Area)
General Storage		
Braced Metal Storage Shelving	5.00	1
Lockable Storage Cabinet	4.95	2
Large Clear Plastic Bins	4.90	3
Built-in Storage Shelving	4.48	4
Equipment/Tool Storage		
Lockable Storage Cabinet	5.24	1

Probe Question Five: What types of facility safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility?

ITEM	Mean	Rank (Question 5)
General Safety Rules Posted	5.81	1
Evacuation Plans	5.71	2
Clear Sightlines within Space for Student Supervision	5.67	T3
Mounted First Aid Kit	5.67	T3
Safety Signs	5.62	4
Quick Communication to Main Office	5.57	5

Shields/Guards on Machines	5.57	5
Kill Switches for Large Equipment	5.52	6
Machine Exhaust System	5.52	6
Machine Specific Safety Rules Posted at Each Machine	5.52	6
Emergency Shut-off Switch	5.33	T7
Eye Wash Station	5.33	T7
Fire Extinguishers	5.33	T7
Fire-resistant Trash Can	5.33	T7
Well Marked Safety Zone Areas	5.38	T7
Flammable Storage Cabinet (Vented)	5.29	8
Regulated Air Connection	5.19	T9
Sink with Soap Dispenser	5.19	T9
Hazardous Chemical Storage Cabinet (Vented)	5.14	10
Direct Exhaust Vents	5.05	T11
Paper Towel Rack	5.05	T11
High-Impact Safety Glass in Divided Areas for Teacher Observation	4.95	12
VCT in production and Storage Areas to Minimize Trip Hazards	4.57	13
Glass Sterilizing/Storage Cabinet	4.90	14

Probe Question Six: What types of personal safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility?

ITEM	Mean	Rank (Question 5)
Eye Protection (Safety Glasses/Goggles)	5.52	1
Face Shields	4.67	2
Dust Masks	4.57	T3
Ear Protection	4.57	T3

Probe Question Seven: What types of hand tools are necessary?

ITEM	Mean	Rank (Question 7)
Scissors	5.35	1
Straight Edges	5.30	2
X-acto Knives	5.26	3
Utility Knives	5.25	4
Hand Drill	5.20	T5
Hot Glue Guns	5.20	T5
Adjustable Wrenches	5.15	T6
Flat Head Screwdrivers	5.15	T6
Phillips Screwdrivers	5.15	T6
Pliers	5.15	T6
Center Punch	5.10	T7
Hack Saw	5.10	T7
Socket Set	5.10	T7
Crescent Wrench Set	5.05	T8
Rubber Mallet	5.05	T8

Wire Snips	5.05	T8
Bench Brushes	5.00	T9
Metric Wrenches	5.00	T9
Soldering Equipment	5.00	T9
Triangles	5.00	T9
Wire Strippers	5.00	T9
Workbench Vises	5.00	T9
Bolt Cutters	4.95	T10
Metric Allen Wrenches	4.95	T10
English Allen Wrenches	4.90	T11
English Wrenches	4.90	T11
Metal Files	4.90	T11
Staple Gun	4.90	T11
Hex Wrenches	4.85	T12
Spring Clamps	4.85	T12
Try Square	4.85	T12
Level	4.80	T13
Magnets	4.80	T13
Plastic Mallet	4.80	T13
Tin Snips	4.80	T13
T-Squares	4.80	T13
Coping Saw	4.79	14
Ball Peen Hammer	4.75	T15
Twist Drills	4.75	T15
Divider	4.70	T16
Nail Set	4.70	T16
Bar Clamps	4.65	T17
Claw Hammer	4.65	T17
Pop Rivet Gun	4.65	T17
Desoldering Iron	4.60	T18
Metal Punch	4.60	T18
Sanding Blocks	4.60	T18
Wood Files	4.60	T18
Electronics Vise	4.55	T19
Tweezers	4.55	T19
Wood Chisels	4.50	20
Cold Chisels	4.35	21

Probe Question Eight: What types of hand held power tools are necessary?

ITEM	Mean	Rank (Question 8)
Cordless Hand Drill	5.00	T1
Dremel Tool	5.00	T1
Jig Saw	4.95	2
Belt Sander	4.75	T3
Corded Hand Drill	4.75	T3
Hot Air Gun	4.70	T4

Hot Wire Cutter	4.70	T4
Solders Gun	4.68	5
Solder Pens	4.58	6
Grinder- with Sandpaper	4.52	7
Skill Saw	4.50	8
Grinder- with Wheel	4.47	T9
Router	4.47	T9
Router Bits	4.47	T9
Strip Heater	4.40	10

Probe Question Nine: What types of material processing equipment are necessary?

ITEM	Mean	Rank (Question 9)
Drill Press	5.10	1
Band Saw	4.95	T2
Table Top Drill Press	4.95	T2
Table Top Band Saw	4.79	3
CNC Mill	4.75	T4
Combo Belt/Disc Sander	4.75	T4
Grinder/Wire Wheel Combo	4.70	5
Air Compressor	4.65	T6
Table Saw	4.65	T6
Scroll Saw	4.50	7
CNC Lathe	4.45	T8
CNC Router	4.45	T8
3D Printer	4.40	9

Probe Question Ten: What types of computer software are necessary?

ITEM	Mean	Rank (Question 10)
Internet Browser	5.48	T1
Word Processing	5.48	T1
3D Modeling/Design and Analytical	5.38	2
Multimedia and Presentation Graphics	5.19	T3
Spread Sheet	5.19	T3
Architectural Design	5.10	4
Animation	4.90	T5
Desktop Publishing	4.90	T5
Software for Programming Robots	4.86	6
Classroom Management and Supervision	4.76	7
Finite Element Modeling	4.71	T8
WestPoint Bridge Builder	4.71	T8
Multimedia Generation and Podcast	4.70	9
VEX Easy C PLC Programming	4.68	10
Electronic Circuit Design	4.67	T11
Engineering Training	4.67	T11
2D CAD	4.57	12

Civil Design	4.52	13
Data Base	4.43	T14
Mechanical Workbench	4.50	T14
PC Control	4.50	T14
Web-Design	4.43	T14
Clip Art	4.48	T15
Electronics Training and Simulation	4.48	T15
Parallax Basic Stamp PLC Programming	4.37	T15
Gaming Development	3.76	16

Probe Question Eleven: What types of audio/visual equipment are necessary?

ITEM	Mean	Rank (Question 11)
Web Access	5.57	1
Computer Projection System (LCD Projector and Projection Screen)	5.14	2
Digital Camera	5.05	3
Scanner	4.95	4
Digital Camcorder	4.81	5
VCR/DVD Combo Player-Recorder	4.76	6
DVD Player	4.62	7
Web Camera	4.57	8
Wireless Pointer	4.40	9
Interactive or Smart Board	4.33	T10
Wireless Mouse	4.33	T10

Probe Question Twelve: What types of measuring and testing devices are necessary?

ITEM	Mean	Rank (Question 12)
Measuring Tape	5.16	T1
Metal Rulers	5.16	T1
Metric Rulers	5.10	2
Engineering Scale	5.05	T3
Micrometers	5.05	T3
Meter Sticks	5.00	T4
Multi-Meters	5.00	T4
Power Supplies	5.00	T4
Stopwatches	5.00	T4
Dial calipers	4.95	5
Architects Scale	4.90	T6
Protractors	4.90	T6
Strain/Stress Gage	4.85	7
Spring Scales	4.75	8
Level	4.74	9
Drafting Tools	4.70	T10
Temperature Sensors	4.70	T10

Adjustable Triangles	4.65	T11
Fast Read Thermometers	4.65	T11
Oscilloscopes	4.65	T11
Pressure Sensors	4.65	T11
Wind Tunnel	4.65	T11
Graduated Metal T-Squares	4.58	12
Laser Level	4.55	13
Transit and Fulcrum	4.55	14
Framing Square	4.50	15
Laser Tape Measure	4.40	16

Probe Question Thirteen: How many computers (and computer related equipment) are necessary?

ITEM	Mean	Rank (Question 13 by Area)
Student Computers		
(1) Computer Per Student for a Total of (28) Student Computers	5.50	1
(1) Dedicated Computer for Each CNC Machine (Robot, Mill, Lathe, and Laser Engraver) in Addition to the Student Computers	4.95	2
Instructor Computers		
(1) Instructor Computer	5.29	1
(1) High Powered Demonstration Computer	4.86	2
(1) Instructor Laptop	4.60	3
Printers		
(1-2) Scanner	5.19	1
(1) Black & White Laser Printer	5.15	2
(1) Color Laser Printer	5.14	3
(1) Large Format CAD Printer/Plotter	5.10	4
General Lab		
(1) Classroom Phone	5.57	T1
Networked Lab with Internet Connection	5.57	T1
(1-2) Digital Still Cameras	5.19	2
(1-2) Dedicated Phone Line	4.95	3
(1-2) Camcorders	4.86	4

Probe Question Fourteen: What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, or other engineering related equipment, if any, are necessary?

ITEM	Mean	Rank (Question 14)
Variety of Robotics Trainers (VEX, Lego Mindstorm, etc.)	4.65	1
Variety of Electronics Basic Electricity Training Kits (Gibson Tech, Tronix, etc.)	4.45	2

Automated Manufacturing Equipment	4.25	3

Probe Question Fifteen: List any other item you feel is necessary for teaching engineering design concepts to high school students.

ITEM	Mean	Rank (Question 15)
Collaboration with Math and Science Teachers	5.55	T1
Partnerships with Local Manufacturers, Business, Engineering Firms, etc	5.55	T1
Engineering Design Notebooks	5.35	T2
Office Supplies	5.35	T2
New Item-Recycle Bin	5.32	3
Masking Tape	5.26	4
Computer Paper	5.25	T5
Dry Erase Markers	5.25	T5
Glue	5.25	T5
Stapler	5.25	T5
Waste Paper Baskets	5.25	T5
Paper Cutter	5.20	6
Clear Tape	5.10	T7
Colored Markers	5.10	T7
Water Fountain	5.10	T7
Hole Punch	5.05	8
Construction Paper	5.00	T9
Reverse Engineering	5.00	T9
Colored Pencils	4.95	T10
State Approved Curriculum	4.95	T10

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter is a review of the rationale and conceptual framework for this study, as well as a review of the statement of purpose, research questions and the method. Findings of the study and the implications of these results as applied to practice and future research within the field of technology education will follow upon completion of this review.

Summary of the Study

Engineering design as a curriculum focus for technology education is gaining wide acceptance from many educators in the field of technology education (Asunda & Hill, 2007; Dearing & Daugherty, 2004; Gattie & Wicklein, 2007; Lewis, 2004, 2005). Engineering design has the potential to enhance the field of technology education with a clearer and more valued curriculum focus (Wicklein, 2006). Students, parents, administrators, and counselors will see a better organized, rigorous curriculum; a curriculum that leads to many high wage, high demand career options for both college and non-college bound students.

A change in curriculum focus will require attention to determining what the technology education facility requirements should be to meet this changing focus. Daugherty et al. (2008) contend “most technology education facilities continue to operate well past the planned life span of classroom and laboratory spaces” (p. 20). School systems often allocate a onetime allotment of money to fund technology education programs. This practice may have been adequate in the industrial arts era, when shop type equipment would last for 20 years or more. As technology education facilities become outdated, a negative perception begins to develop among students, parents, and school administration within the school building. The negative perception has severe implications for the instructor. As support and interest starts to diminish, the instructor will struggle to attract students to meet the minimum class size requirement. As enrollment drops, administrators are faced with the decision to close the program. Daugherty et al. stated that "outdated facilities not only impact the curriculum and the instructor's ability to offer a contemporary standards-based learning experience, but also influence student and public perceptions of the program" (p. 20).

In order to meet changing curriculum foci and combat the negative perceptions that lead to the closing of technology education programs, the technology education facility design must be addressed. It is imperative that professionals in the field of technology education, including teachers, administrators, and faculty at teacher preparation institutions, have access to research based information. That information must speak directly to the issues and details regarding the facilities that support engineering design focused curriculum. Within the *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards (AETL)* (ITEA, 2003), standard P-4 highlights the need for technology education teachers to help all students develop the skills for planning and implementing learning environments that facilitate technological literacy. The standard reads: "Guidelines for meeting standard P-4 require that teacher(s) responsible for technology program(s) consistently: a) create and manage learning environments that are supportive of students interactions and students abilities to question, inquire, design, invent, and innovate; b) create and manage learning environments that are up to date and adaptable; c) implement a written, comprehensive safety program; d) promote student development of knowledge and abilities that promote safe application of technological tools, machines, materials and processes; e) verify that the number of students in the technology education laboratory-classroom does not exceed its capacity" (ITEA, 2003, p. 124).

It is clear from the literature there is need for research with regard to technology education facilities encompassing engineering design as a curriculum focus (Advisory Committee on Engineering and Technology Education in Georgia, 2008; Daugherty et al., 2008; Gattie & Wicklein, 2007; Kelley, 2008; Smith, 2006).

Purpose and Research Questions

The purpose of this study was to determine the instructional facility requirements critical to teaching engineering content in high school environments. To determine the essential features of these facilities, a coordinated group of experts provided informed feedback about the requirements necessary for developing this type of learning environment. This study was guided by the following research questions:

1. What are the laboratory/facility requirements- in terms of various instructional spaces and their size (square footage) - necessary for teaching engineering and technology at the high school level?
2. How should high school engineering and technology laboratories be configured for teaching engineering concepts?
3. How should high school engineering and technology laboratories be equipped for teaching engineering concepts?

These research questions were designed to be open-ended and broad in order to help professionals in the field of technology education establish the instructional laboratory requirements critical for including engineering design in the technology education facility.

Methodology and Measures

The Delphi process is an appropriate research methodology for the purposes of this study. The Delphi method is especially suited for facilitating the interaction of a widely dispersed panel of participants. Participants in this study were identified by their peers through a logical, repeatable process that sought to find the most knowledgeable professionals associated with the topic of instructional facility requirements critical to teach engineering content in high school environments. Many phases of this Delphi process, including contacting participants and administering survey instruments, were carried out through the Survey Monkey web-based research service. Each survey was available online for 15 to 30 days, and participants received email reminders that instructed them to access the website in order to fill out the survey.

This study utilized a three-round Delphi process in order to identify items that would answer the three research questions. In Round 1, participants were asked to record responses to each of the research questions that were the focus of this study. A total of 1246 responses were received from the 24 participants. This data was reviewed by University of Georgia faculty members Drs. Robert Wicklein (Major Professor), Roger Hill, John Mativo, Jay Rojewski, and Kenneth Tanner, so they could review the entire list of responses and help condense the data into a list of unique items. Their review established a list of 442 unique responses. These items became the basis for Round 2.

The Round 2 survey instrument consisted of the 442 items identified in Round 1. For each individual item the 24 participants were asked to indicate their level of agreement on a six-point Likert-type scale. A higher mean score indicated a higher level of agreement that the item was an appropriate answer to the research question. In addition to indicating their level of agreement with each item, participants were free to add additional items in response to the research questions if they wished.

The Round 3 survey instrument consisted of the original 442 items identified in Round 1 plus two items added in Round 2 for a total of 444 total items. Participants again accessed the survey electronically and indicated their level of agreement on a six-point, Likert-type scale. In addition, the mean, median, standard deviation, and inter-quartile (IQR) range were reported alongside each item. Participants were also emailed their Round 2 scores as a reminder. As in Round 2, participants were encouraged to provide an explanation of their score on any item that was outside the IQR.

The results of the Delphi process were analyzed and reported in Chapter 4 of this dissertation. It was decided to identify items as very important only if they met the highest standards. These standards were:

1. Median score of 5 or 6
2. IQR of ≤ 1
3. Inter-round Δ mean of $< 15\%$

Two hundred and fifty four (254) items met these standards and are identified in Table 4.9.

Implications of Study Findings

As professionals from the field of technology education continue to struggle with the best strategies for equipping and configuring engineering focused technology education facilities, several conclusions can be drawn from this research. As states start to move toward an engineering focused curriculum, professionals in the field of technology education should make use of research-based content as it relates to planning for today's engineering focused technology education facility. The development of facilities that emphasize engineering design should be prefaced by present and future anticipated enrollments, local and world technological trends, program philosophy and goals, the instructional delivery system, and the availability of monetary resources. Currently there is no overarching framework for understanding and implementing engineering focused technology education facilities with regards to secondary education.

This Delphi study was carefully constructed in such a way as to identify the necessary tools and equipment needed for modern day engineering design focused technology education facilities. Given the educational constraint of having 28 high school students utilizing a given classroom/laboratory, this study also identifies educational and auxiliary room specifications (size and furnishings), safety considerations, measuring and testing devices, computer hardware and software, audio visual equipment, and engineering focused kits and trainers in a meaningful and quantifiable method.

There are numerous groups of people that could benefit from these findings. First and foremost is the technology educations teacher. No one in the technology education program is better qualified to synthesize this study to assist in the process of laboratory planning than the secondary classroom teacher. The typical high school technology teacher has the unique training in drawing and design using CAD systems and the relationships between various tools and equipment used during instructional activities. The technology education teacher has an overall understanding of laboratory requirements and can express them verbally, and graphically. A well trained and experienced technology education teacher can be extremely helpful in advising on various matters that should receive attention with regards to facility construction and renovation.

Undergraduate students in teacher preparation programs majoring in technology education is another group which stands to benefit from this type of research. Teacher preparation programs often fail to provide instruction concerned with facility planning and construction. Historically, young teachers have often found themselves involved in assisting in the creation of plans for a new facilities or altering a laboratory already in existence (Nair, 1959). There is no doubt that incorporating an engineering focused curriculum will continue to provide the opportunity for new and existing teachers to redesign and configure instructional facilities.

There continues to be a high level of turnover in career and technical education administration at all levels, (i.e., local, county, and state) in recent years (Georgia Department of Education, 2008). This study was designed to give existing and new leaders in career and technical education who may not have the expertise in the area of technology education the necessary material for assisting with the design of new or existing technology education facilities focused on engineering design.

Architects have an overwhelming job when planning and designing new schools or additions within existing schools. Many educational laboratories require special physical conditions to insure optimum teaching and learning. Band, chorus, art and most career and technical education programs (i.e., business and computer science, family consumer science, as well as technology education) require specific facilities; many of which are mandated through state departments of education. This study was designed to aid and assist architects with the planning of new or renovated engineering focused technology education facilities.

Conclusions from Delphi Results

The first major conclusion to be drawn from this research is how professionals from the field of technology education have identified instructional and support spaces they deemed necessary for the inclusion of engineering design as a curriculum focus for 28 students and 1 instructor. Participants in this study were able to identify and indicate a high level of agreement with six instructional items. Those items suggested five instructional spaces that should be included in a technology education facility that emphasizes engineering design. One point of interest was that participants were in agreement with 2 different square foot choices of prototyping, and materials processing laboratory. In addition, participants identified two support spaces they felt should be included in a technology education facility that emphasizes engineering design. This research identified the following:

Instructional Spaces

1. 1000 to 1500 square foot combination computer, lecture, and presentation area.
2. 1200 to 1800 square foot flexible workspace for project staging, materials testing, creative problem solving, and team work space.
3. 1000 to 1300 square foot prototyping, materials processing. laboratory or 2000 to 2300 square foot prototyping, materials processing laboratory.
4. 250 square foot CNC, CIM, and Rapid Prototyping area.
5. 200 square foot research and resource area.

Support Spaces

1. 200 to 250 square foot general storage and supply room.
2. 100 to 150 square foot equipment and tool storage room.

These findings suggest an overall square foot range of 3950 to 5450 for an engineering focused technology education facility that incorporates a prototyping, materials processing laboratory of 1000 to 1300 square feet. A range of 4950 to 6450 square feet was suggested for an engineering focused technology education facility that incorporates a prototyping, materials processing laboratory of 2000 to 2300 square feet.

A second conclusion to be drawn from this research is how professionals from the field of technology education have identified furnishings for each instructional and support space necessary for the inclusion of engineering design as a curriculum focus for 28 students and 1 instructor. Participants in this study were able to identify and indicate a high level of agreement with thirteen items identified for the combination computer, lecture, and presentation area; nine items identified in the flexible workspace for project staging, materials testing, creative problem solving, and team work space; ten items identified for the prototyping, materials processing laboratory; three unique items identified for the general storage and supply room; and one item identified for the equipment and tool storage room. There were no items identified for furnishing the CNC, CIM, and Rapid Prototyping area or research and resource area. The lists of furnishings broken down by area as identified by this research are:

Combination Computer, Lecture, and Presentation Area

1. Bookshelf storage case
2. Bulletin Board
3. Combinations CAD/Drafting student workstations
4. Computer style chairs
5. Rolling Adjustable Chairs
6. Display cabinet with shelves
7. File cabinet
8. Instructor work station/desk
9. Lockable storage cabinet
10. Marker board
11. Multimedia cabinet
12. Printer table
13. Projection screen

Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work Space

1. Activity storage cabinet with tote trays
2. Adjustable stools
3. Lockable storage supply cabinets
4. Mobile material and activity cart
5. Printer table
6. Prototype and testing stations
7. Standard height student worktables
8. Storage cabinet
9. Teacher command station

Prototyping, Materials Processing Laboratory

1. Activity storage cabinets with tot trays
2. Demonstration table
3. Large sink
4. Lockable storage/supply cabinets
5. Mobile materials and activity cart
6. Standing height shop style workbenches
7. Stools
8. Storage lockers for student work
9. Tool storage cabinet
10. Wall mounted tool cabinets

General Storage and Supply Room

1. Braced metal storage shelving or built in storage shelving
2. Large plastic see through bins
3. Lockable storage cabinet

Equipment and Tool Storage Room

1. Lockable storage cabinet

A third conclusion to be drawn from this research is how professionals from the field of technology education have identified facility and personal safety materials necessary for safe work environments for students and teachers who work within the engineering focused technology education facility for 28 students and 1 instructor. Participants in this study were able to identify and indicate a high level of agreement with twenty-three unique facility safety items and four unique personal safety items which they deemed necessary to include in a technology education facility that emphasizes engineering design. The research identified the following:

Facility Safety

1. Clear sight line within the space for student supervision
2. Direct exhaust vents for each machine
3. Emergency shut off switch
4. Evacuation plans
5. Eye wash station
6. Fire extinguishers
7. Fire resistant trash can
8. Flammable storage cabinet
9. General safety rules posted
10. Safety glass sterilizing storage cabinet
11. Hazardous chemical storage cabinet
12. High impact safety glass in divided areas for teacher observation
13. Machine specific safety rules posted at each machine
14. Mounted first aid kit
15. Paper towel rack
16. Quick communication to main office
17. Regulated air connection
18. Safety signs
19. Shield and guards on machines
20. Sink with soap dispenser
21. VCT in production and storage areas to minimize trip hazards
22. Water Fountain
23. Well marked safety zone area

Personal Safety

1. Dust masks
2. Ear protection
3. Eye protection
4. Face shields

A fourth conclusion to be drawn from this research is how professionals from the field of technology education have identified tools, equipment, engineering trainers, and measuring and test equipment, as well as some basic supplies necessary for delivering engineering concepts within the engineering focused technology education facility for 28 students and 1 instructor. Participants in this study were able to identify and indicate a high level of agreement with fifty-one hand tools; thirteen unique power hand tools; eleven unique large pieces of material processing equipment; three engineering trainers/kits; twenty-five measuring and test devices; and sixteen general supply items. The research identified the following:

Hand Tools

1. Adjustable Wrenches
2. Ball Peen Hammer
3. Bar Clamps
4. Bench Brushes
5. Bolt Cutters
6. Center Punch
7. Claw Hammer
8. Coping Saw
9. Crescent Wrench Set
10. De-soldering Iron
11. Divider
12. Electronics Vise
13. English Allen Wrenches
14. English Wrenches
15. Flat Head Screwdrivers
16. Hack Saw
17. Hand Drill
18. Hex Wrenches
19. Hot Glue Gun
20. Level
21. Magnets
22. Metal Files
23. Metal Punch
24. Metric Allen Wrenches
25. Metric Wrenches
26. Nail Set
27. Phillips Screwdrivers
28. Plastic Mallet
29. Pliers
30. Pop Rivet Gun
31. Rubber Mallet
32. Sanding Blocks
33. Scissors
34. Socket Set
35. Soldering Equipment
36. Spring Clamps
37. Staple Gun
38. Straight Edges
39. Tin snips
40. Triangles
41. Try Square
42. T-Squares
43. Tweezers
44. Twist Drills
45. Utility Knives
46. Wire Snips
47. Wire Strippers
48. Wood Chisels
49. Wood Files
50. Workbench Vises
51. X-acto Knives

Hand Held Power Tools

1. Belt sander
2. Corded Hand Drill
3. Cordless Hand Drill
4. Dermal Tool
5. Grinder
6. Hot Air Gun
7. Hot Wire Cutter
8. Jig Saw
9. Router with bits
10. Skill Saw
11. Solder Pens
12. Solder Gun

13. Strip Heater

Material Processing

1. 3D Printer
2. Air Compressor
3. Band Saw
4. CNC Lathe
5. CNC Mill
6. CNC Router
7. Combo Belt/Disc Sander
8. Drill Press
9. Grinder/Wire Wheel Combo
10. Scroll Saw
11. Table Saw

Engineering Trainers/Kits

1. Automated Manufacturing Equipment – as specified within the material process equipment
2. Variety of Electronics, basic electricity training kits (Gibson Tech, Tronix, etc)
3. Variety of Robotics Trainers (VEX, LEGO Mindstorm, etc)

Measuring and Test Devices

1. Adjustable Triangles
2. Architects Scale
3. Dial Calipers
4. Engineering Scale
5. Fast Read Thermometers
6. Framing Square
7. Graduated Metal T-Square
8. Laser Level
9. Laser Tape Measure
10. Measuring Tape
11. Metal Rulers
12. Meter Stick
13. Metric Ruler
14. Micrometers
15. Multi-Meters
16. Oscilloscope
17. Power Supplies
18. Pressure Sensors
19. Protractors
20. Spring Scales
21. Stopwatches
22. Strain/Stress Gage
23. Temperature Sensors
24. Transit and Fulcrum
25. Wind Tunnel

General Supply Items

1. 3 hole punch
2. Clear tape
3. Colored markers
4. Colored pencils
5. Computer paper
6. Construction paper
7. Dry erase markers
8. Engineering design notebooks
9. Glue
10. Masking tape
11. Paper cutter
12. Stapler
13. Waste paper baskets
14. Recycle bin

A fifth conclusion to be drawn from this research is how professionals from the field of technology education have identified computer software, computer hardware and audio visual equipment necessary for the engineering focused technology education facility for 28 students and 1 instructor. Participants in this study were able to identify and indicate a high level of agreement with twenty unique computer software programs, fourteen unique computer and computer related hardware for student and teacher use, and unique audiovisual devices for student and teacher use. The research identified the following:

Computer Software

1. 2D CAD
2. 3D Modeling/Design and Analytical
3. Animation
4. Architectural
5. Civil Design
6. Classroom management and supervision
7. Clip art
8. Data base
9. Desktop Publishing
10. Electronics training and simulation
11. Engineering Training
12. Internet Browser
13. Mechanical workbench
14. Multimedia and presentation graphics
15. Multimedia generation and podcast
16. Software for programming robots – PLC
17. Spread Sheet
18. Web-Design
19. WestPoint Bridge Builder
20. Word Processing

Computer Hardware

Student Use

1. One computer per student – computer number should match the maximum class size, for example maximum class size of 28 students per sections there should be 28 student computers.
2. One dedicated computer for each CNC machine that has been incorporated in the facility; i.e. CNC - Robot, Mill, Lathe, Laser Engraver etc.

Teacher Use

1. Instructor Computer - Suggested that teacher computer be high powered demonstration computer
2. Laptop Computer

Printers/Peripherals
1. Black and White Laser Printer
2. Color Laser Printer
3. Large Format CAD Printer/Plotter
4. Scanner

General Peripherals
1. Classroom phone
2. Dedicated phone line
3. Networked lab with internet connection
4. Web Camera
5. Wireless Mouse
6. Wireless Pointer

Audio Visual
1. Computer projection system
2. Digital camcorder
3. Digital camera
4. Interactive or Smart Board
5. VCR/DVD combo player

A sixth conclusion to be drawn from this research is how professionals from the field of technology education have four additional items that do not fall within any one particular area necessary for the engineering focused technology education facility. The research identified the following:

Other items

1. Collaboration with Math and Science teachers
2. Partnerships with local manufactures, business, and engineering firms
3. Reverse engineering
4. State approved curriculum

From this research, an engineering design focused technology education support final report was produced. It included facility specifications such as sample facility layout drawings, furnishings, safety considerations, tool and equipment list, and computer software/hardware specifications (see Appendix J).

Flexible Engineering Design Laboratory (FED-LAB)

Technology education facilities have always had changing needs stemming back to the manual training movement, thru the industrial arts, and technology education eras. Now a new focus has begun that incorporates an engineering design focus. During the manual training movement facilities were rigidly planned for one area of instruction called unit laboratories. With a transition to the industrial arts, facilities were more general in scope called comprehensive general laboratory. Yet another transition caused a complete paradigm shift and the modular lab was established to meet the needs of the technologically focus curriculum. In general, facility changes steam from a variety of reasons; (a) new and innovative curriculum focus; (b) new and exciting program initiatives; (c) changing relationship between schools and communities; (d) shifts in societal issues; (d) change in technology or technological advancements; and (e) changes with delivery of educational content.

The challenge to school facility planners in general, is that facilities are expected to last forty years without major renovation, but the programs they serve may change several times in that time period just as technology education facilities continue to change. Most architects, and educational planners, focus attention in their planning processes on current practices and needs. This leaves little room for futuristic thinking. Long term success for new engineering design focused technology education facilities will depend on two truths that must be accepted and accounted for when planning facilities; (1) the long term future will not be like it is today, technology education will continue to evolve and may make any future facility design obsolete; (2) schools will continue to be under funded. Professionals from the field of technology education may debate the first point, but the second point is a truism in education.

Any new technology education facility whether or not it includes focus on engineering design must be designed for affordability, and it must be legitimately flexible enough to change with new curriculum developments. Thus the results of the study lends to a flexible engineering design laboratory or FED-Lab. The FED-Lab concept incorporates adaptable multi task spaces. These spaces are designed to accommodate a variety of tasks; much like a good multi-tool can be used for any number of functions (i. e. one tool that incorporates many functions – pliers, screwdriver, knife, etc). The different spaces within the FED-Lab can be used for a variety of instructional activities. For example the computer lab area can be used for the following; (a) teaching software applications (i. e. 3d modeling); (b) classroom space for lecture; (c) student presentation area – for groups of students to communicate different solutions to problems; (d) sketching and drafting; (e) group planning and research; and (f) teacher/student demonstration. These are only a few tasks that may be accomplished within the computer lab area.

A second area found to be significant within the FED-Lab was the flexible workspace. This space provides an area for project staging, materials testing, problem solving, and teamwork. The furniture within this space is flexible and on caster making it easy to move around to different locations or configurations as deemed suitable by the instructor to meet curriculum needs. The furniture is relatively inexpensive and can be replaced as curriculum needs change. Electrical and data is configured so not to be in the way by being on reels hung from the ceiling. This enables the instructor and student to pull power or data from the ceiling when needed. Within this space instructors are able to incorporate new and innovative curriculum options. They are not bound to furniture, electrical, data, or lab configuration constraints. The instructor can setup a large empty space where robotics fields can be set up for student competition, to a space where students can work in large, or small, groups as well as individually depending on the activity set by the instructor.

A third area found to be significant within the FED-Lab was the prototyping/material processing area. I considered this space to be a dirty space where students will prototype a variety of projects using materials such as woods, metals, and plastics. For this reason I believe the area should be separated from the clean spaces (computer area, and flexible workspace) and equipped with machinery used for processing woods, metals, and plastics. Though this space has larger equipment it still is flexible in nature because of the various tools housed within the space (i. e. hand tools, power tool, and heavy machinery) that process any number of different materials into prototypes.

Replacing the Modular Technology Education Lab

From the findings of this dissertation one could conclude that the modular technology education laboratory is no longer considered to be the accepted laboratory for delivering engineering focused technology education content. This conclusion can be drawn by the feedback from the following probe questions presented to participants; (1) What types of instructional spaces are necessary?; (2) How should each instructional space be configured?; (3) How should each instructional space be furnished?; (4) What types of software are necessary?; and (5) What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, and any other engineering related equipment (if any) are necessary? None of the expert participants within this study reported the following standard modular technology facility items to be significant; (1) modular area as an instructional space; (2) cubical office space as a configuration option; (3) modular furniture as a furniture option; (4) module management system, or module specific software as a software option, and (5) list of modules by any one vendor as a kit option.

Early critics of modular laboratory instruction dated as far back as Dobrauc, Harnisch, and Jerich (1995); Dean and Crockett (1996); and Pullias (1997). Pullias (1997) stated that:

Student experiences provided with modular labs are what can be considered lower level. All the students have to do is follow directions. They really don't have an opportunity to develop and use creative problem-solving skills, or to demonstrate a true understanding of the various concepts being addressed. A great deal of money is being spent on environments with an impressive, attractive ambiance that attracts attention but does not provide student's opportunities to go beyond the cut-and-dry rote activities of the modular lab. (p. 29)

The reality of the modular concept was that school districts spend, difficult to obtain money on facilities that were absent of strong educational merit.

Within this dissertation a new facility design has been suggested. The design and specifications are found in the final report (Appendix J). A more flexible engineering design focused technology education facility the researcher has named the Flexible Engineering Design Lab or FED-Lab for short. The FED-Lab incorporates the educational theory known as constructivism which is based on the foundational works of Dewey, Piaget, and Vygotsky (Bransford, Brown, & Cocking, 2000). The basic philosophy is, "people construct new knowledge and understanding based on what they already know and believe" (Bransford et al., 2000, p. 10). The FED-Lab was designed to be able to include the following constructivist concepts: (a) learner centered--pay attention to the students' preconceptions, skills and attitudes; (b) knowledge centered--pay attention to the subject, student understanding and mastery; (c) Assessment centered--use frequent formative assessment by both the teacher and the student to monitor progress; (d) community centered--The context of learning is important. Combined argumentation plus cooperation enhances cognitive development.

In addition the FED-Lab provides opportunities to incorporate the Center for Occupation Research and Development five key strategies to actively engage students in a constructivist approach to teaching in exemplar classrooms. These five strategies are: (1) relating--learning in the context of one's life experiences or preexisting knowledge; (2) Experiencing--learning by doing, or through exploration, discovery, and invention; (3) applying--learning by putting the concepts to use; (4) cooperating--learning in the content of sharing, responding, and communication with others; (5) Transferring--using knowledge in a new context or novel situation--one that has not been covered in class.

Within the FED-Lab instructors are able to affordably infuse engineering design, problem solving, and analytical skills. The FED-Lab provides opportunities for students to archive the following engineering-related concepts: (1) interpersonal skills, including teamwork, group skills, attitude and work ethic; (2) the ability to communicate ideas verbally and orally; (3) working within constraints; (4) ability to brainstorm and generate ideas; (5) ability to assess product design; (6) ability to troubleshoot technological devices; (7) ability to understand mathematical and scientific equations; (8) understanding of various engineering fields; (9) gain experience developing a portfolio; (10) ability to possess basic computing skills. The FED-Lab is flexible enough to accommodate engineering focused technology education programs that share both general education purposes as well as vocational purposes. This is based on the fact that both philosophy's share the following educational goals (a) students will develop a deep and rich understanding of the term technology, (b) students will develop their abilities to use the engineering design process; (c) students will understand the complementary relationships among science, technology and engineering; (d) students will understand how advances in technology affect human society, and how human society determines which new technologies will be developed; and (e) students will be able to apply fundamental concepts about energy to a wide variety of problems. The concepts taught in general education programs are the same as the concepts taught in vocational programs the difference between engineering design programs with general education goal and vocational goals are the level of students enrolled within each program. A typical scenario for general education programs is: (a) students come from all grade levels (9-12); and (b) students come from varying levels of academic achievement (low, medium, and high); and (c) these students are all in one class mixed together. The difference between vocational programs is the opposite: (a) students usually come from the same grade level and are usually grouped with other classes such as an accelerated or AP Math or Science course; and (b) most typically students are high academic achievers with strong math and science backgrounds, and are interested in engineering as a serious career option; and (c) engineering courses are taught in a logical sequence of study.

Recommendations

After completing this 3 round Delphi study and compiling the results from each round, there were several recommendations for future research that can be made. These recommendations fall into three categories: future research, project based learning and teacher preparations.

Recommendations for Future Research and Instruction

1. Although this study sought to make a contribution to the development of a comprehensive technology education facility that focuses on engineering design as a curriculum organizer, further research is needed. There are specific curriculum aspects of

technology education that need to be addressed in order for the knowledge-base in this area to be complete enough to make a widely accepted lab design a reality. They are listed below:

a. Student Achievement

Earthman (2004) sites several studies that link student achievement with appropriate and modern equipped and configured laboratories. Additional research should be conducted to compare technology education facility types linked to student achievement. A comparison study could be conducted between tradition industrial arts facilities, modular technology education facilities and engineering design focused technology education facilities using any number of standardized tests, engineering assessments, or technical literacy exams as a measure of achievement.

b. Vocational or General Education

Engineering is becoming widely accepted as a curriculum focus by many in the field of technology education, though opinions about the way in which engineering should be infused vary greatly. Positions range from engineering as a vocation, where technology education would take on the role of pre-engineering. The main focus would be to prepare high school student who wish to attend a university pursuing engineering as a career. In contrast, others from the profession believe that engineering should retain a broad focus in which engineering design "as simply one of many forms of creative activity" is infused in the technology education curriculum (Hill, 2006, p. 46). Research is needed to develop an understanding of facility requirements that distinguish differences between technology education programs that focus on engineering as a vocation, and programs in which engineering is part of general education.

c. Engineering Concepts

There have been a number of studies that have identified engineering concepts that are important to emphasize within the technology education curriculum (Childress & Rhodes, 2007; Dearing & Daugherty, 2004; Hailey et al., 2005; Smith, 2006). Research is needed to link engineering concepts to specific tools and equipment necessary for inclusion into engineering focused technology education facilities. Studies could provide valuable information about outcomes and competencies achieved by students within an engineering focused technology education facility.

d. Successful Implementation

There are several documented works in recent professional literature that have given examples of newly designed technology education facilities (Daugherty et al., 2008). This suggests an opportunity to conduct qualitative case studies of high school technology education teachers, or administrators that have successfully implemented an engineering design focused technology education facility. These types of studies could seek to explore the challenges and constraints facing teachers, administrators, and school districts as they implement a new technology education facility focused on engineering design.

2. This study could be expanded by focusing on additional areas that fall within technology education. Many states allow for additional curriculum organizers, called pathways. Additional pathways include animation, manufacturing, multimedia and game design,

engineering graphics, energy system, and electronics to name a few (Georgia Department of Education, 2008). Additional studies might focus on other areas that fall under the technology education umbrella and the facility requirements necessary for their successful implementation in the curriculum. It would also be beneficial to include more female and minority participants in future studies.

3. Technology education programs have, historically, utilized project-based learning as a pedagogy that prepares learners for new learning expectations by conceiving, developing, and implementing projects relevant to the learners' and the communities' needs. This active learning process teaches critical thinking, problem solving, teamwork, negotiation skills, reaching consensus, using technology, and taking responsibility for one's own learning. If technology education is to enjoy sustained growth as a profession it must enhance the features of the physical learning environment that support and enhance collaborative, project-based learning at the K-12 level. Smith (2006) found that engineering design-focused curriculum should include a hands-on component because prototyping/fabrication skills rated high among professionals from the field of engineering as important for students to learn. This high rating prompted Smith (2006) to suggest a change in technology education facilities was needed to reflect engineering design. Smith listed the following categories as areas of concern: (a) functionality and size of instructional and auxiliary spaces, (b) furnishings, (c) safety, (d) equipment, and (e) computer hardware and software. If engineering design is to be incorporated into the technology education curriculum we must continue to zero-in on what are the most critical and necessary components of these types of facilities. Further research should be

conducted to determine what components of an engineering design focused technology education are most critical for incorporating project based learning.

4. Teacher preparation colleges and universities need to incorporate facility design activities into undergraduate and graduate programs. This type of instruction will provide future technology education teachers with information on planning, designing, and implementing engineering focused technology education facilities. Students should gain a historical perspective, as well as glimpses at future trends with regards to laboratory design and facility planning. Given proper instruction, students in these programs will be able to design and create a model technology education facility, create equipment and supply lists, and formulate safety requirements and issues for students at the secondary and post secondary levels.

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APPENDIX A

LETTER TO POINT OF CONTACT FOR SUB-GROUPS

College of Education
Workforce Education, Leadership, and Social Foundations

Date

Name
Company/Institution
Address Line 1

Dear (Name):

I am a doctoral student at the University of Georgia completing my dissertation study, *Planning for the Inclusion of Engineering Design in the Technology Education Facility: Using the Delphi Technique*. You were identified as a point of contact for your field of expertise because of your extensive background and knowledge and your highly respected reputation. My doctoral committee members, Drs. Robert Wicklein (Major Professor), Roger Hill, John Mativo, Jay Rojewski, and Kenneth Tanner, have suggested I contact you requesting your help establishing a pool of experts in one of the following fields for my research.

6. University professors specializing in teaching engineering and technology to future teachers.
7. University professors specializing in teaching engineering to future engineers.
8. Individuals specializing in the construction of school facilities.
9. Expert engineering and technology high school teachers.
10. Career technology education administrators.

This study will rely on the Delphi technique to elicit the responses of a geographically diverse group of experts. They will identify the instructional laboratory facility requirements critical to teach engineering and technology in high school environments.

If you agree to participate, you will be asked to identify the names, email addresses, and mailing addresses of 10 persons you feel are qualified as experts in your given field. From this list, we will select approximately 5-10 participants from each sub-group for this study.

As you can see, the beginning of this entire study relies on your participation. I hope this does not assume too much, but we feel that your reputation and work qualifies you to identify other experts in your field.

Thank you for considering involvement in this study. If you are not able to help me at this time please advise me of this as well. I will be happy to answer any questions you might have. I hope to hear from you very soon.

Sincerely,
Paul Camick

APPENDIX B

INITIAL CONTACT EMAIL FOR SUB-GROUPS

College of Education
Workforce Education, Leadership, and Social Foundations

Date

Name
Company/Institution
Address Line 1

Dear (Name):

I am a doctoral student at the University of Georgia completing my dissertation, *Planning for the Inclusion of Engineering Design in the Technology Education Facility: Using the Delphi Technique*. You were identified as a potential participant because of your extensive background and knowledge and your highly respected reputation. (Name) at/from (School or Business) suggested I contact you to request your help establishing a pool of experts in one of the following fields for my research.

1. University professors specializing in teaching engineering and technology to future teachers.
2. University professors specializing in teaching engineering to future engineers.
3. Individuals specializing in the construction of school facilities.
4. Expert engineering and technology high school teachers.
5. Career technology education administrators.

This study will rely on the Delphi technique to elicit the responses of a geographically diverse group of experts. They will identify the instructional laboratory facility requirements critical to teaching engineering and technology in high school environments.

If you agree to participate, you will join a study conducted via the Internet that will consist of 3 rounds of surveys. Each round should take no more than 30 minutes to complete.

As you can see, the beginning of this entire study relies on your participation. I hope this does not assume too much, but I feel that your reputation and work qualifies you to participate in this study with other experts in your field. This is a crucial step in my study and I cannot go forward until I gain qualified participants.

Thank you for considering involvement in this study. If you are not able to help me at this time please advise me of this as well. I will be happy to answer any questions you might have. I hope to hear from you very soon.

Sincerely,
Paul Camick

APPENDIX C

ROUND ONE SURVEY

Round One Survey

1. What should the overall facility size be for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor?
2. What types of instructional spaces are necessary?
3. What types of support spaces are necessary?
4. How should each instructional space be configured?
5. How should each support space be configured?
6. How should each instructional space be furnished?
7. How should each support space be furnished?
8. What types of facility safety materials are necessary to provide a safe environment for all students working in the facility?
9. What types of personal safety materials are necessary to provide a safe environment for all students working in the facility?
10. What type of security equipment is essential for securing the facility?
11. What types of hand tools are necessary?
12. What types of hand held power tools are necessary?
13. What types of material processing equipment are necessary?
14. What types of software are necessary?
15. What types of audio visual equipment are necessary?
16. What types of measuring and testing devices are necessary?
17. How many computers and pieces of computer related equipment (printers, scanners, laser engravers, 3D printers, etc.) are necessary?
18. What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, and any other engineering related equipment (if any) are necessary?

APPENDIX D

ROUND ONE EMAIL

To: Prospective research participants
From: Paul Camick
Reference: Laboratory Requirements for Engineering and Technology Education

I need your valuable insight. I am conducting research to determine the instructional laboratory facility requirements critical to teach engineering and technology in high school environments. The *Determining the Instructional Laboratory Facility Requirements Critical for Including Engineering Design in the Engineering and Technology Education Facility* is available at the following link:
http://www.surveymonkey.com/s.aspx?sm=cWQEyePsUYuL2_2fGcO22ajg_3d
Please take a few minutes to complete the first of three on-line surveys and submit it no later than **(June 1st)**. Read all the directions carefully prior to completing the survey instrument. Your honest and professional responses are needed so that an accurate analysis can be accomplished. Your participation will involve completing three on-line surveys and should take no more than 30 minutes for each survey. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty. Be assured that your responses will be held in strict confidence; only group results of this research will be reported. The results of the research study may be published, but your name will not be used. In fact, the published results will be presented in summary form only. Your identity will not be associated with your responses in any published format.

The findings from this project may provide engineering and technology teachers and career and technical education administrators' research based information for aiding in the implementation of engineering and technology education laboratories. Teachers and administrators will be able to refer to the study to help them in their selection of facility design and configuration, major equipment purchases, textbooks, curriculum, computer hardware and software. In addition, the result of this study could establish an accurate budget necessary for school systems to allocate for the purpose of implementing an engineering focus in high schools environments. The results of the study are important to the field of engineering and technology education and will provide invaluable insight into the improvement of engineering and technology education. There are no known risks or discomforts associated with this research.

Please note that Internet communications are insecure and there is a limit of confidentiality that can be guaranteed due to the technology itself. However, once I receive the completed surveys, I will store them in a locked cabinet and will destroy them and any names and contact information that I have shortly after the end of the study. If you are not comfortable with the level of confidentiality provided by the Internet, please feel free to print out a copy of each survey as they become available, fill them out by hand, and mail it to me at the address on the survey, with no return on the envelope

If you have any questions about this research project, please feel free to call me, Paul Camick, at (770) 723-2185 or send an e-mail to pcamick@uga.edu. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 612 Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

Thank you in advance for your prompt return of the first survey and commitment for the additional 2 that will follow. Be assured that your input is providing a valuable service to the profession of engineering and technology education as well as overall efforts in educational reform. We will be pleased to send you a summary of the survey results if you desire. By completing and returning this survey, you are agreeing to participate in the above described research project. Please keep this letter for your records. Thank you for your cooperation.

APPENDIX E

ROUND ONE SURVEY RAW DATA

Round One Survey
Raw Data
Instructional Spaces

The following are responses to question 1: What types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor (i.e. Computer Lab, Prototyping/Material Processing Lab, etc.)? Please list the space and square footage for each. (Example: computer lab-1200 square feet).

1.	CAD/Computer Lab	1200 sqft.
2.	Class meeting/lecture/presentation area	340 sqft.
3.	Classroom	nothing given
4.	Classroom wt/raised stadium seating	500 sqft.
5.	Classroom	800 sqft.
6.	Classroom/CAD Lab	1200-1500 sqft.
7.	Classroom/Computer lab	1200 sqft.
8.	Clean Area (classroom/computer)	1200-1400 sqft.
9.	CNC/CIM/Rapid Prototyping area	250 sqft.
10.	Collaborative Space for Design Teams	1200 sqft.
11.	Computer area	1000 sqft
12.	Computer facilities	1000 sqft.
13.	Computer Lab	1000 sqft.
14.	Computer Lab	1200 sqft.
15.	Computer Lab	1200 sqft.
16.	Computer Lab	1500 sqft.
17.	Computer lab	1500 sqft.
18.	Computer Tech Lab	1800 sqft.
19.	Computer workstation area	2500 sqft.
20.	Computer/Design Lab	1200 sqft.
21.	Computer/Drawing and Sketching	1000 sqft.
22.	Computing and Design	1200 sqft.
23.	Construction Lab	3000 sqft.
24.	Design and Brainstorming Area	250 sqft.
25.	Design Lab	800 sqft.
26.	Design/Prototyping Lab	2000 sqft.
27.	Eng/tech lab	1850 sqft
28.	Engineering Prototyping	1600 sqft.
29.	Engineering Room	600 sqft.
30.	Engineering/Tech lab	1200 sqft.
31.	Fabrication area for prototype dev.	2240 sqft.
32.	Fabrication Room	700 sqft.

33. Integrated computer/CAD lab	nothing given
34. Lab Work area	1250 sqft.
35. Laboratory Area	2400 sqft.
36. Lecture area	250 sqft.
37. Lecture/Computer lab	1000 sqft.
38. Manufacturing/Material processing Lab	3000 sqft.
39. Manufacturing/Material Processing	400 sqft.
40. Material Processing	2000sqft.
41. Materials Lab	750 sqft.
42. Materials Processing Lab	1240 sqft
43. Materials testing space	1000 sqft.
44. Mechanical Prototyping Shop	3600 sqft.
45. Multipurpose Area	1200 sqft.
46. Multipurpose lab area	2500 sqft.
47. Open Lab Area	1000-1200 sqft.
48. Planning and design area	1000 sqft.
49. Production Area	1000 sqft.
50. Production Facility	1200 sqft.
51. Production Lab	800 sqft.
52. Project staging/testing area	2000 sqft.
53. Prototyping	800 sqft.
54. Prototyping area	2600-3600 sqft.
55. Prototyping Lab	nothing given
56. Prototyping/material Processing	500 sqft.
57. Prototyping/testing Area	1000 sqft.
58. Research/resource area	200 sqft.
59. Seating Area (lecture, presentations, demo)	400 sqft.
60. Seating area	900 sqft.
61. Testing Lab (wind tunnels, etc.)	100 sqft.
62. Universal Lab/Shop-Prototyping	120 sqft.
63. Video Production	350 sqft.
64. Workspace for assembly/problem solving	1200 sqft.

Round One Survey
Raw Data
Support Spaces

The following are responses to question 2: What types of support spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor (i. e. Storage, Office, etc.)? Please list the space and square footage (example: storage room- 200 square feet).

1.	Activity and storage	200 sqft.
2.	Equipment and material storage	300 sqft.
3.	Equipment Storage	100 sqft.
4.	Equipment Storage	150 sqft.
5.	Equipment Vault	500 sqft.
6.	Faculty Office	130 sqft.
7.	Faculty Office	130 sqft.
8.	Material Storage	150 sqft.
9.	Materials Storage	400 sqft.
10.	Materials Storage	400 sqft.
11.	Office	200 sqft.
12.	Office Space	150 sqft.
13.	Office Space	200 sqft.
14.	Office Space	200sqft.
15.	Office	100 sqft.
16.	Office	150 sqft.
17.	Office	200 sqft.
18.	Office	75sqft.
19.	Office	80- 100sqft.
20.	Office	nothing given
21.	Printing space for Plotter and 3d solid printer	100sqft.
22.	Project Storage Area	144 sqft.
23.	Project Storage	200 sqft.
24.	Project Storage	400 sqft.
25.	Project Storage	700sqft.
26.	Project Storage	nothing given
27.	Server Closet	100 sqft.
28.	Storage	200 sqft.
29.	Storage	250sqft.
30.	Storage Room	130 sqft.
31.	Storage Room	130 sqft.
32.	Storage Room	200 sqft.
33.	Storage Room	750 sqft.
34.	Storage Space	200sqft.

35. Storage Space	nothing given
36. Storage	75 sqft.
37. Supply Storage Area	144 sqft.
38. Supply Storage	100 sqft.
39. Supply	150sqft.
40. Teacher Office/Resource Materials	144 sqft.
41. TSA Officers Office	150 sqft.
42. Video Development/Quiet space	200 sqft.

Round One Survey
Raw Data
Instructional Space Furnishings

The following are responses to question 3: How should each instructional space be furnished? (Example: computer lab- (28) student computer desks, (1) teacher desk, (1) printer table, etc.)

1. 30” x 72” Computer Desks
2. 36” Computer Desk
3. Activity Storage Cabinets with Tote Trays
4. Book Shelves
5. Book Storage Shelf
6. Built in Cabinets/Counter Tops for student work
7. Bulletin Boards
8. Bulletin Boards
9. Carpeted floors
10. CNC/CIM/Rapid Prototyping area counter/tables
11. Columned Notebook Racks
12. Combo- CAD/Drafting Student Workstations
13. Computer /Lecture Station
14. Computer Desk
15. Computer Desk
16. Computer Style Chairs
17. Computer Tables
18. Computer Tables
19. Computer Tables
20. Computer Tables
21. Computer Tables
22. Computer Tables
23. Computer Tables
24. Computer Workstations
25. Computer/Drafting Tables with elevated monitors
26. Demonstration Table
27. Design Pods with conference table seating that accommodates 3 computers-- for 6 students.
28. Display Cabinet
29. Display Shelves
30. Document Storage File Cabinet
31. Drafting Tables
32. Durable Theater Seats with writing surface
33. Filing Cabinets
34. Individual Student Computer Tables
35. Instructor Desk with chair and Lockable storage cabinets
36. Instructors desk
37. Large standing height shop style workbenches
38. Lockable Storage Cabinets
39. Magazine Rack
40. Marker Boards
41. Marker Boards
42. Material Storage Cabinets
43. Mobile Material and Activities Cart
44. Multimedia Cabinet
45. Open shelving
46. Planning Tables
47. Portable Standing Height Student Work Tables
48. Portable student tables
49. Printer Table
50. Printer Table
51. Printer Table
52. Printer Table
53. Printer Table
54. Printer Table
55. Printer Table
56. Printer Table
57. Printer Table
58. Printer table
59. Printer table
60. Printer Tables
61. Projection Screen

62. Projector Table
63. Prototype and testing stations with adjustable stools
64. Raised seating
65. Rolling adjustable chairs
66. Round Tables
67. Round Tables
68. Service Carts
69. Shop Work Benches
70. Sink
71. Standard Student Desks
72. Stools
73. Stools with Adjustable Backs
74. Storage Cabinets
75. Storage lockers for student projects
76. Student Chairs
77. Student Chairs
78. Student Chairs
79. Student Computer Desk
80. Student Computer Desks
81. Student Computer Desks
82. Student computer tables
83. Student Desks
84. Student Work Table
85. Student Work Tables
86. Student Workstations containing 1 computer per 2 students
87. Students chairs (not on rollers)
88. Sturdy work tables for production Lab
89. Supply Storage Cabinet
90. Table for printing
91. Teacher Command Center
92. Teacher Desk
93. Teacher Desk
94. Teacher Desk
95. Teacher Desk
96. Teacher Desk
97. Teacher Desk
98. Teacher Desk with lockable cabinet
99. Teacher lecture and demonstration table
100. Teacher Station
101. Teacher work station/desk
102. Teacher Work Table
103. Tool Lockers
104. Tool Storage Cabinet
105. Traditional school desks
106. Wall Tool Cabinets
107. Work Stations similar to module stations
108. Work Tables
109. Work Tables
110. Workbenches
111. Worktables

Round One Survey
Raw Data
Support Space Furnishings

The following are responses to question 4: How should each support space be furnished?

(Example: storage- (1) lockable storage cabinet, (1) material storage rack, etc.)

1. Book Storage Shelves
2. Book/Multimedia Storage Shelf
3. Braced Metal Storage Shelving
4. Built in Cabinets and Shelves
5. Cage Type access project Storage
6. Counter top space
7. Filling Cabinets
8. Large Plastic see-through bins
9. Lockable Equipment Storage
10. Lockable Filing Cabinets
11. Lockable Material Storage
12. Lockable Shelving/Storage Cabinet
13. Lockable Storage Cabinet and large shelves to store books and materials
14. Lockable Storage Cabinets
15. Lockable Storage Cabinets
16. Lockable Storage Cabinets
17. Lockable Storage Cabinets
18. Lockable Storage Cabinets
19. Lockable Storage Cabinets
20. Lockable Storage Cabinets
21. Material Storage Racks
22. Material Storage Racks
23. Material Storage Racks
24. Materials Storage Rack
25. Materials Storage Racks
26. Materials Storage Shelves
27. Open Shelving for Books and Resource Materials
28. Portable Wire Shelving Carts with Wheels and Plastic organizer containers
29. Project Storage Racks
30. Rolling shelving system
31. Shelves
32. Shelving
33. Shelving Hanging Hooks and Locking cabinets
34. Shelving Units
35. Storage Cabinets
36. Storage Racks and Cabinets
37. Storage Shelves
38. Supply Cabinets
39. Teacher Chair
40. Teacher Desk
41. Teacher Desk
42. Teacher Desk
43. TSA officer Desk
44. Vertical Storage Space
45. Wire Storage Racks

Round One Survey
Raw Data
Facility Safety

The following are responses to question 5: What types of facility safety materials are necessary to provide a safe environment for all students working in the facility (i.e. eye wash station, hazardous chemical storage cabinet, first aid kit, etc.)?

1. Air Cleansing/Dust Collection Equipment
2. Air Filtration Unit
3. All Safety Devices necessary for Industrial Arts and Technology
4. Approved Cabinet for Storing Paints
5. Basic First Aid Kit
6. Chemical Shower
7. Clear Sight lines within Space for Student Supervision
8. Direct Exhaust Vents
9. Ear Plugs
10. Emergency Power Switches
11. Emergency Shut Off
12. Emergency Shut Off Switch
13. Evacuation Plans
14. Eye Wash
15. Eye Wash Station
16. Eye Wash Station
17. Eye Wash Station
18. Eye Wash Station
19. Eye Wash Station
20. Eye Wash station
21. Eye Wash Station
22. Eye Wash Station Hazardous Chemical Storage Cabinet
23. Eyewash
24. Eyewash
25. Eyewash Station
26. Eyewash Station
27. Eyewash Stations
28. Fire Cabinet
29. Fire Extinguisher
30. Fire Extinguisher
31. Fire Extinguishers
32. Fire Extinguishers
33. Fire Resistant Trash Can
34. Fire Suppression
35. First Aid Kit
36. First Aid kit
37. First Aid Kit
38. First Aid Kit
39. First Aid Kit
40. First Aid Kit
41. First Aid Kit
42. First Aid Kit
43. First Aid Kit
44. First Aid Kit Restroom with Emergency Chemical Shower wt/floor Drain
45. First Aid Kits
46. First Aid Kits
47. Fixed First Aid Station
48. Flammable Storage Cabinet
49. Flammable Storage Cabinet
50. Flammable Storage Cabinet (Vented)
51. Flammable Storage Locker
52. Hand Wash Station
53. Hazardous Chemical Storage Cabinet
54. Hazardous Chemical Storage Cabinet (Vented)
55. Hazardous Material Cabinet
56. Hazardous Material Storage
57. Hazardous Materials Cabinet
58. Hazardous materials Storage
59. High-Impact Block Walls
60. High-Impact Safety Glass in Divided Areas for Teacher Observation—
61. Kill Switches for Large Equipment
62. Lab Kill Switch Buttons
63. Locked Tool Cabinet

64. Locking Storage Cabinet
65. Machine Exhaust System
66. Machine Specific Safety Rules Posted at Each Machine
67. Mounted First Aid Kit Safety Glass Sterilizing/Storage Cabinet
68. Paper Towel Rack
69. Portable Air Filtering
70. Purge Equipment
71. Quick Communication to Main Office
72. Regulated Air Connection
73. Safety Eye Glass Cabinet
74. Safety Glass Cabinet
75. Safety Glass Cabinet
76. Safety Glass Cabinet
77. Safety Glass Storage
78. Safety Goggles
79. Safety Rules Posted
80. Safety Signs
81. Safety Zone Areas
82. Safety Zones
83. Safety Zones Demarcation Hardware
84. Sealed Concrete Floors
85. Several Fire Extinguishers
86. Shields on Machines
87. Shower
88. Sink
89. Sink
90. Sink with Soap Dispenser
91. Smocks
92. UV Eyeglass Storage Cabinet
93. VCT in production and Storage Areas to minimized Trip Hazards

Round One Survey
Raw Data
Personal Safety

The following are responses to question 6: What types of personal safety materials are necessary to provide a safe environment for all students working in the facility? (i. e. safety glasses, ear protection, etc)

1. Aprons
2. Chemical Aprons
3. Coveralls
4. Disposable Ear Plugs
5. Disposable Ear protection
6. Dust Masks
7. Ear Plugs
8. Ear Protection
9. Ear Protection
10. Ear Protection
11. Ear Protection
12. Ear Protection
13. Ear Protection
14. Ear Protection
15. Ear Protection
16. Eye Protection
17. Eye Protection
18. Eye Safety Glasses
19. Eye/Head Shields
20. Face Mask
21. Face Shields
22. Fire Extinguishers
23. Glasses
24. Gloves
25. Gloves
26. Hair Pulled Back
27. Hand Wash Area
28. Hard Hat
29. Heavy Duty Gloves
30. No Baggy Clothes
31. No Jewelry
32. No Long Sleeves
33. Protective Clothing
34. Respirators with Disposable Filters
35. Safety Glasses
36. Safety Glasses
37. Safety Glasses
38. Safety Glasses
39. Safety Glasses
40. Safety Glasses
41. Safety Glasses
42. Safety Glasses
43. Safety Glasses
44. Safety Glasses
45. Safety Glasses
46. Safety Glasses
47. Safety Goggles
48. Welding Safety Equipment
49. Work Gloves

Round One Survey
Raw Data
Hand Tools

The following are responses to question 7: What types of hand tools are necessary? (i. e. hammer, wrenches, screwdriver, etc.).

1. Adjustable Wrenches
2. Allen Wrenches
3. Allen Wrenches
4. Allen wrenches
5. Allen Wrenches
6. Architect Scales
7. Assorted Screw Drivers
8. Ball Peen Hammer
9. Ball Peen Hammers
10. Bar Clamps
11. Bench Brushes
12. Bolt Cutters
13. C-Clamps
14. Center Punch
15. Chisel Set
16. Chisels
17. Chisels
18. Chuck Keys
19. Clamps
20. Clamps
21. Clamps
22. Clamps
23. Claw Hammer
24. Cold Chisels
25. Coping Saw
26. Coping Saw
27. Crescent Wrench Set
28. Crosscut Saw
29. Desoldering Iron
30. Divider
31. Drill Bit Set
32. Electrical Wire Cutter
33. Electronics Vise
34. English Allen Wrenches
35. English Wrenches
36. Etching System
37. File Card
38. Files
39. Files
40. Files
41. Files
42. Files
43. Flat Head Screwdrivers
44. General Hand Tools for Multi-Purpose Light Industrial Design Environment
45. Hack Saw
46. Hack Saw
47. Hack Saws
48. Hammer
49. Hammer
50. Hammer
51. Hammers
52. Hammers
53. Hammers
54. Hammers
55. Hammers
56. Hammers
57. Hammers Screwdrivers
58. Hand Drill
59. Hand Saw
60. Hand Saws
61. Hand Seamer
62. Hand Seamier
63. Hex Wrenches
64. Hot Glue Gun
65. Hot Glue Guns
66. Level
67. Magnets
68. Mallet
69. Measuring Tape
70. Measuring Tapes
71. Metal Files
72. Metal Punch
73. Metal T-Squares
74. Metric Allen Wrenches
75. Metric Wrenches

76. Micrometers
77. Nail Set
78. Open End Wrenches
79. Pencils
80. Phillips Screwdrivers
81. Plastic Mallet
82. Pliers
83. Pliers
84. Pliers
85. Pliers
86. Pliers Set
87. Pop Rivet Gun
88. Punches
89. Right Triangles
90. Rubber Mallet
91. Rulers
92. Rulers
93. Rulers
94. Rulers
95. Sanding Blocks
96. Scissors
97. Scissors
98. Scissors
99. Scratch Awl
100. Screw Driver Set
101. Screwdrivers
102. Screwdrivers
103. Screwdrivers
104. Screwdrivers
105. Screwdrivers
106. Screwdrivers
107. Screwdrivers
108. Screwdrivers
109. Screwdrivers
110. Scribes
111. Shears
112. Small Saw
113. Socket Set
114. Socket Set
115. Socket Wrenches
116. Soldering Equipment
117. Soldering Gun
118. Soldering Irons
119. Soldiering Equipment
120. Spring Clamps
121. Staple Gun
122. Straight Edges
123. Tape Measure
124. Tape Measure
125. Tin Snips
126. Torque Wrenches
127. Triangles
128. Try Squares
129. T-Squares
130. Tweezers
131. Twist Drills
132. Universal Hand Tool Cabinet that Contains many Basic Hand Tools
133. Utility Knives
134. Wire Cutters
135. Wire Snips
136. Wire Strippers
137. Wire Strippers
138. Wood Chisels
139. Wood Files
140. Wood Shaving Tools
141. Workbench Vises
142. Wrenches
143. Wrenches
144. Wrenches
145. Wrenches
146. Wrenches
147. Wrenches
148. Wrenches
149. X-acto Knives
150. X-acto Knives
151. X-acto Knives
152. Yard Sticks
153. Yard Sticks

Round One Survey
Raw Data
Hand Power Tools

The following are responses to question 8: What types of hand held power tools are necessary? (i. e. cordless drill, sander, angle grinder, etc.)

1. 3" Grinders
2. Angle Grinder
3. Angle Grinders
4. Assorted Air Tools
5. Belt Sander
6. Belt Sander
7. Buffer
8. Circular Saw
9. Circular Saw
10. Circular Saw
11. Circular Saw
12. Circular Saws
13. Corded Drill
14. Cordless Drill
15. Cordless Drill
16. Cordless Drill
17. Cordless Drills
18. Cordless Drills
19. Cordless Hand Drill
20. Cordless Hand Drill
21. Cordless Screwdrivers
22. Dremel
23. Dremel Tool
24. Dremel Tool
25. Dremel Tool and Tool Set
26. Dremel Tools
27. Drill
28. Drill
29. Drill
30. Drill
31. Drill
32. Drill Bits
33. Drill Press
34. Drills
35. Electric Chisels
36. Engraving Equipment
37. Grinder
38. Grinder
39. Grinder- with Sandpaper
40. Grinder- with Wheel
41. Hand Held Belt Sander
42. Hot Air Gun
43. Hot Wire Cutter
44. Jig Saw
45. Jig Saw
46. Jig Saw
47. Jig Saw
48. Jig Saw
49. Jig Saw
50. Jig Saw
51. Jig Saw
52. Jig Saws
53. Laminate Trimmer Bits
54. Multi-Meters
55. Orbital Sander
56. Orbital Sander
57. Orbital Sanders
58. Pad Sander
59. Palm Sanders
60. Palm Sanders
61. Plastic Heat Strip
62. Plastics Welder
63. Pneumatic Nail Gun
64. Portaband (for metal Cutting
65. Portable Power Supplies
66. Power Drill
67. Rotary Cutter
68. Router
69. Router Bits
70. Sander
71. Sander
72. Sanders
73. Sanders
74. Sanders
75. Saws All
76. Screw Guns

77. Sheet Metal Shear
78. Skill Saw
79. Skill Saw
80. Skill Saw
81. Skill Saw
82. Skill Saw
83. Solder Pens
84. Solders Gun
85. Strip Heater
86. Volt Meters
87. Wafer Doweling Tool

Round One Survey
Raw Data
Material Processing Equipment

The following are responses to question 9: What types of material processing equipment are necessary? (i. e. table saw, drill press, arc welder, CNC mill, laser engraver, etc.)

1. 110v Mig Welder
2. 3D Printer
3. 3D Printer
4. 3D Solid Printer
5. Air Compressor
6. Air Compressor
7. Air Compressor
8. Arc Welder
9. Arc Welder
10. Arc Welder
11. Arc Welder
12. Autonomous Robot
13. Band Saw
14. Band Saw
15. Band Saw
16. Band Saw
17. Band Saw
18. Band Saw
19. Band Saw
20. Band Saw
21. Band Saw
22. Band Saw
23. Band Saw
24. Band Saw
25. Band Saws
26. Belt and Disc Sander
27. Belt Sander
28. Belt Sander
29. Belt Sander
30. Bench Top Drill Press
31. Cabinet Saw
32. CIM CELL with Robotic Arm, and Conveyor Belt
33. CNC Lathe
34. CNC Lathe
35. CNC Lathe
36. CNC Lathe
37. CNC Machine
38. CNC Mill
39. CNC Mill
40. CNC Mill
41. CNC Mill
42. CNC Mill
43. CNC Mill
44. CNC Mill
45. CNC Mill
46. CNC Mill
47. CNC Mill
48. CNC Mill
49. CNC Router
50. Combo Belt/Disc Sander
51. Combo Belt/Disc Sander
52. Combo Belt/Disc Sander
53. Cut Off Saw
54. Cut Off Saw
55. Disk Sander
56. Drill Press
57. Drill Press
58. Drill Press
59. Drill Press
60. Drill Press
61. Drill Press
62. Drill Press
63. Drill Press
64. Drill Press
65. Drill Press
66. Drill Press
67. Drill Press
68. Drill Press Band Saw
69. Drill Press Compound Sliding Miter Saw
70. Foam Cutter
71. Grinder
72. Grinder
73. Grinder
74. Grinder

75. Grinder
76. Grinder
77. Grinder/Wire Wheel Combo
78. Jointer
79. Jointer
80. Jointer
81. Laser Engraver
82. Laser Engraver
83. Laser Engraver
84. Laser Engraver
85. Laser Engraver
86. Lathe
87. Metal Band Saw
88. Metal Brake
89. Metal Foot Shear
90. Metal Lathe
91. Metal Slip Rollers
92. MIG Welder
93. Miter Saw
94. Miter Saw
95. Miter Saw
96. Miter Saw Belt Sander
97. Oxy-Acetylene Unit
98. Planer
99. Plastic Injection Molder
100. Plastic Vacuum Forming Machine
101. Plastics Machine (multi-purpose)
102. Prototyping Machine
103. Radial Arm Saw
104. Radial Arm Saw
105. Router
106. Saw Stop Table Saw
107. Scroll Saw
108. Scroll Saw
109. Scroll Saw
110. Scroll Saw
111. Sheet Metal Tools
112. Sliding Compound Miter Box
113. Small MIG/Arc Welder Combo
114. SNC Lathe
115. Spindle Sander
116. Spindle Sander
117. Spot Welder
118. Standing Height Drill Press
119. Table Saw
120. Table Saw
121. Table Saw
122. Table Saw
123. Table Saw
124. Table Saw
125. Table Saw
126. Table Saw
127. Table Saw
128. Table Saw
129. Table Saw
130. Table Saw
131. Table Top Band Saw
132. Table top Drill Press
133. Table Top Table Saw
134. Thermo Fax Machine
135. Thermo former
136. TIG Welder
137. Torch Welder
138. Variable Speed Drill Press
139. Vinyl Sign Machine
140. Welding Equipment
141. Wire Feed Welder
142. Wood Lathe

Round One Survey
Raw Data
Computer Software

The following are responses to question 10: What types of computer software are necessary? (2D design, 3D design, presentation software, etc.)

1. 2D CAD
2. 2D CAD
3. 2D CAD
4. 2D CAD
5. 2D CAD
6. 2D CAD
7. 3 Dimensional Parametric CAD
8. 3D CAD
9. 3D CAD
10. 3D CAD
11. 3D CAD
12. 3D CAD
13. 3D CAD
14. 3D CAD
15. 3D CAD
16. 3D Design
17. 3D Design and Analytical Software (Like ProE)
18. 3D Design and Simulation Stress Analysis
19. 3D Modeling
20. Adobe Photoshop
21. Adobe Photoshop
22. Adobe Suite
23. Adobe Suite
24. Animation
25. Any 3 D Software
26. Architectural
27. Architectural Design
28. Architectural Software
29. AutoCAD
30. CAD
31. CAD
32. CAD Software
33. Civil Design
34. Clip Art
35. CNC Support
36. Corel Draw
37. Corel Draw
38. Data Base
39. Desktop Publishing Software
40. Dictionary Software
41. Draw Software
42. Electronic Circuit Design Software
43. Electronics Training and Simulation
44. Electronics Workbench
45. Engineering Training Software
46. Excel
47. Excel
48. Excel
49. Finite element Modeling
50. Gaming
51. General Office Software
52. Google Sketch up
53. Graphic Design
54. Graphic Design Software
55. Graphics Software
56. Internet
57. Internet Browser
58. Inventor
59. Inventor
60. Inventor 3D Software
61. Mastercam
62. MathCAD
63. MathCAD
64. Matlab
65. Mechanical Workbench
66. Microsoft Office Suite
67. Modeling Software
68. MS Office
69. MS Office
70. MS Office Suite
71. MS Office Suite
72. MS Project
73. Multimedia Generation and Podcast
74. Multimedia Generation and Presentation

75. Parallax Basic Stamp PLC Programming Software
76. PC Control Software
77. Power Point
78. Power Point
79. Power Point
80. Power Point
81. Predictive Analysis
82. Presentation
83. Presentation Graphics Software
84. Presentation Software
85. Presentation Software
86. ProE
87. Publisher
88. Revit
89. Revit
90. Revit
91. Sign or Banner Making Software
92. Simple Video Editing Software
93. Simulation Software
94. Simulation Software
95. Simulation Software
96. Simulations
97. Software for Programming Robots
98. Solid Modeling Software
99. Solid Works
100. Spread Sheet
101. Spread Sheet Software
102. Spreadsheet
103. Spreadsheet
104. Spreadsheet
105. Spreadsheets
106. Text Processing
107. VEX Easy C PLC Programming Software
108. Video Editing
109. Video Editing Software
110. Visualization Software
111. Web Design
112. Web-Design
113. WestPoint Bridge Builder
114. Word
115. Word
116. Word Processing
117. Word Processing
118. Word Processing
119. Word Processing
120. Word Processing Software

Round One Survey
Raw Data
Audio Visual

The following are responses to question 11: What types of audio visual equipment are necessary? (VCR, LCD projector, interactive board, etc.)

1. Cable TV Access
2. CD
3. Classroom Management Software
4. Computer Display-Touch Sensor
5. Computer Projection System
6. Convex Mirrors for student Supervision
7. Digital Camcorder
8. Digital Camera
9. Document Camera
10. DVD
11. DVD Player
12. DVD Player
13. DVD Player
14. DVD Player
15. DVD Player
16. DVD Recorder
17. Elmo Type Projector
18. Interactive Board
19. Interactive Board
20. Interactive Board
21. Interactive Board
22. Interactive Board
23. Interactive Tablet
24. Lab Management Software
25. LCD Projector
26. LCD Projector
27. LCD Projector
28. LCD Projector
29. LCD Projector
30. LCD Projector
31. LCD Projector
32. LCD Projector
33. LCD Projector
34. LCD Projector
35. LCD Projector
36. Marker Board
37. Multimedia Player
38. Projection Equipment
39. Projection Screen
40. Projection System
41. Projector Screen
42. Room Microphones and Speakers
43. Scanner
44. Scrolling Message Board
45. Smart Board
46. Smart Board
47. Smart Board
48. Smart Board
49. Smart Board
50. Smart Board
51. Stereo/CD player and Speakers
52. Surround Sound
53. TV Set
54. VCR
55. VCR
56. VCR
57. VCR/DVD Combo
58. VCR/DVD Combo player-recorder
59. Video Camera
60. Video Projector
61. Web Access
62. Web Camera
63. Wireless Access for Audio
64. Wireless Mouse
65. Wireless Pointer
66. Write Pad

Round One Survey
Raw Data
Measuring and Test Devices

The following are responses to question 12: What types of measuring and testing devices are necessary (measuring tape, micrometers, materials tester, etc.)?

1. Adjustable Triangles
2. Altimeter Gun
3. Architect Scales
4. Architects Scale
5. Bench Rule
6. Calibrated Rulers
7. Caliper
8. Calipers
9. Compression tester
10. Computer Interfaced Structural Tester
11. Device for Measuring Length
12. Device for Measuring Weight
13. Dial calipers
14. Digital Multi-Meter
15. Digital Scale
16. Drafting Tools
17. Engineering Scale
18. Engineers Scales
19. English Ruler
20. Fast Read Thermometers
21. Framing Square
22. GPS Tracking Device
23. Graduated Metal T-Squares
24. Handheld Multi-Meter
25. Hydrometer
26. Large Fixed Strength Testing
27. Large Package Shipping Scale (600lbs)
28. Laser Level
29. Laser Tape Measure
30. Level
31. Light Guns
32. Materials Tester
33. Materials Tester
34. Materials Tester
35. Measuring Tape
36. Measuring Tape
37. Measuring Tape
38. Measuring Tape
39. Measuring Tape
40. Measuring Tapes
41. Measuring Tapes
42. Measuring Tapes
43. Measuring Tapes
44. Measuring Tapes
45. Metal Rulers
46. Meter Stick
47. Meter Stick
48. Meter Sticks
49. Metric Ruler
50. Metric Rulers
51. Micrometer
52. Micrometer
53. Micrometer
54. Micrometers
55. Micrometers
56. Micrometers
57. Micrometers
58. Micrometers
59. Micrometers
60. Micrometers
61. Micrometers
62. Micrometers
63. Micrometers
64. Vernier Calipers
65. Multi-Meter
66. Multi-Meters
67. Oscilloscopes
68. PH Sensors
69. Postage Scale
70. Power Supplies
71. Power Supply
72. Precision Measuring Equipment
73. Pressure Sensors
74. Printer Scale
75. Protractors
76. Rulers

77. Rules
78. Scale
79. Scale Micrometers
80. Scopes
81. Speed Square
82. Spring Scales
83. Steel Rules
84. Stop Watches
85. Stopwatches
86. Strain/Stress Gage
87. Strength Analyzer
88. Strength Analyzer
89. Stroboscope
90. Tape Measure
91. Tape Measure
92. Temp Gage
93. Temperature Gage
94. Temperature Sensors
95. Timer
96. Transit and Fulcrum
97. Triple Balance Beam with Weights
98. Triple Beam Scales
99. Weight Scale
100. Weight Scale
101. Wind Tunnel
102. Wood Rulers
103. Yard Stick
104. Yard Stick

Round One Survey
Raw Data
Computer Equipment

The following are responses to question 13: How many computers and computer related equipment (printers, scanners, 3D printers, etc.) are necessary? Please list device and quantity (Example: 30- computers, 1- color laser printer, etc.).

1. (1) 3D Digitizer
2. (1) 3D Printer
3. (1) 3D Printer
4. (1) 3D Printer
5. (1) 3D Printer
6. (1) 3D Printer
7. (1) 3D Rapid Prototype Printer
8. (1) B & W Laser Printer
9. (1) B & W Printer
10. (1) B & W Printer
11. (1) Black and White Laser Printer
12. (1) Camera and Monitor System
13. (1) Classroom Phone
14. (1) Color Laser Printer
15. (1) Color Laser Printer
16. (1) Color Laser Printer
17. (1) Color Laser Printer
18. (1) Color Laser Printer
19. (1) Color Laser Printer
20. (1) Color Printer
21. (1) Color Printer
22. (1) Computer Monitoring System
23. (1) Computer Per Student
24. (1) Dedicated Computer for each computer controlled device (i.e. CNC-Mill, Lathe, and Robot, Laser Engraver, 3D Printer)
25. (1) Dedicated Computer for Each CNC Machine
26. (1) Dedicated Phone Line
27. (1) Digital Camera
28. (1) Fax
29. (1) Flat-Bed Scanner
30. (1) Instructor Computer
31. (1) Instructor Computer
32. (1) Instructor Computer
33. (1) Large Format Printer
34. (1) Large Format Printer/Plotter
35. (1) Large Scale Plotter
36. (1) Large Size Plotter
37. (1) Laser Engraver
38. (1) Laser Jet Printer
39. (1) Laser Printer
40. (1) Plastic Sign Making Printer/Plotter
41. (1) Plotter
42. (1) Plotter
43. (1) Plotter
44. (1) Scanner
45. (1) Scanner
46. (1) Scanner
47. (1) Teacher Computer
48. (1) Teacher Computer
49. (1) Teacher Computer
50. (1) Teacher Laptop
51. (1) Vinyl Sign Machine
52. (15) Student Computers
53. (2) Camcorders
54. (2) Color Laser Printers
55. (2) Dedicated Phone Lines
56. (2) Digital Cameras
57. (2) Digital Still Cameras
58. (2) Faculty Computers
59. (2) Instructional Computers
60. (2) Printers
61. (2) Scanners
62. (2) Teacher Computers
63. (2) Video Editing Stations
64. (28) Computers
65. (28) Student Computers
66. (28) Student Computers
67. (28) Student computers
68. (28) Student computers

69. (28) Student Computers
70. (28) Student Computers
71. (28) Student Computers
72. (30) Computers
73. (30) Computers
74. (30) Computers
75. (30) Computers
76. (4) B & W Laser Printers
77. (4) Inkjet Printer
78. (4) Laptops for TSA Competitions
79. (4) Student Laptops dedicated for TSA conference competitions
80. (45) Computers
81. (6) Student Computers
82. (7) Computers
83. 3D Printer
84. 3D Printer
85. 3D Printer
86. A & B Size Color Printer
87. All printer Networked
88. Black and White Laser Printer
89. Color Laser Printer
90. Color Laser Printer
91. Dedicated Computer for Each CNC Machine (Robot, Mill, Lathe, and Laser Engraver) in addition to the student computers.
92. High Powered Demonstration Computer
93. Large Format CAD Printer
94. Large Scale Plotter
95. Networked Color Laser Printer
96. Networked Lab with internet connection
97. Plotter
98. Plotter
99. Scanner
100. Scanner

Round One Survey
Raw Data
Engineering Equipment/Kits

The following are responses to question 14: What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, and any other engineering related equipment (if any) are necessary? Please list with description and quantity.

1. Alternative Energy Systems Kits and Trainers
2. Automated Manufacturing Equipment
3. Automated Manufacturing Trainer (Robot with CNC Machines)
4. Bread Boards
5. Breadboards
6. CIM Cell Set
7. Circuit Cidesign Kits
8. Civil Engineering Trainer Kit
9. Electrical Motor Kits
10. Electricity Trainer
11. Electronics
12. Electronics
13. Electronics
14. Electronics Trainer
15. Electronics Trainer Kits
16. Electronics Trainers
17. Electronics Trainers— Tronix
18. Fischer Tech Interfacing
19. GibsonTech Electronics Kits
20. Gibtech Digital Electronics Kits
21. Hydraulics Trainer
22. Kits aren’t necessary
23. Lego Mindstorm
24. LEGO NXT
25. Lego-Logo Interfacing
26. Mechanisms Trainer
27. No Packaged Kits or Trainers
28. None
29. Pneumatics Trainer
30. Precision Measurement Trainer
31. Robotic Kits
32. Robotic Microcontroller Kits
33. Robotics
34. Robotics Kits
35. Robotics Kits
36. Robotics Kits
37. Robotics Kits
38. Robotics Kits
39. Robotics Trainer
40. Sensors and Transducers Kit
41. Tronix Electronics Basic Electricity Training Kits
42. Variety of Robotics Kits
43. Vex Robotic
44. Vex Robotics
45. Vex Robotics Kits

Round One Survey
Raw Data
Engineering Equipment/Kits

The following are responses to question 15: List any other item you feel is necessary for teaching engineering design concepts to high school students that you were unable to list for another question.

1. 3 Hole Punch
2. Clear Tape
3. Collaboration with Math and Science Teachers
4. Colored Markers
5. Colored Pencils
6. Computer Paper
7. Construction Paper
8. Dry Erase Markers
9. Engineering Design Notebooks
10. Engineering Notebooks
11. Glue
12. Internet Access
13. Kelvin Pole
14. Masking Tape
15. Office Supplies
16. Paper Cutter
17. Partnerships with local manufacturers, business, engineering firms, etc.
18. Play Dough
19. Reverse Engineering
20. Separate Lecture Hall
21. Stapler
22. State Approved Curriculum
23. Tissue Paper
24. Turn Key Project Lead the Way Curriculum
25. Waste Paper Baskets
26. Water Fountain

APPENDIX F

ROUND TWO SURVEY INSTRUMENT

Round Two Survey

The following 22 items are responses to Question 1: What Types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Combination Computer/Lecture/Presentation Area—(Various Square Footages)

1. (1000 to 1500 Square Foot) Combination Computer, Lecture, Presentation Area.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. (1800 to 2500 Square Foot) Combination Computer, Lecture, Presentation Area.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

One Room Multipurpose Lab

3. (1000 to 1200 Square Foot) Multipurpose Room for entire lab.

Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work—(Various Square Footages)

4. (250 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.
5. (600 to 800 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.
6. (1000 to 1200 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.
7. (1800 to 2000 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.
8. (2400 to 2600 Square Foot) Flexible Workspace for project staging, materials testing, creative problem solving, and team work.

Prototyping/Material Processing—(Various Square Footages)

9. (120 Square Foot) Prototyping/Material Processing Area.
10. (500 to 800 Square Foot) Prototyping/Material Processing Area.
11. (1000 to 1300 Square Foot) Prototyping/Material Processing Area.
12. (2000 to 2300 Square Foot) Prototyping/Material Processing Area.
13. (2600 Square Foot) Prototyping/Material Processing Area.
14. (3000 Square Foot) Prototyping/Material Processing Area.
15. (3600 Square Foot) Prototyping/Material Processing Area.

Separate Classroom/Lecture Space—(Various Square Footages)

16. (500 Square Foot) Classroom/Lecture Space with Raised Stadium Seating.
17. (250 to 500 Square Foot) Classroom/Lecture Space- standard student desks.
18. 800 to 1000 Square Foot Classroom/Lecture Space- standard student desks.

Various Options

19. (250 Square Foot) CNC/CIM/Rapid Prototyping Area.
20. (100 Square Foot) Testing Lab.
21. (200 Square Foot) Research/Resource Area.
22. (350 Square Foot) Video Production Room.

Round Two Survey

The following 16 items are responses to Question 2: What types of support spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Office

1. (70 to 100 Square Foot) Instructor Office Space.

   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

2. (130 to 150 Square Foot) Instructor Office Space.

   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. (200 Square Foot) Instructor Office Space.

General Storage

4. (75 to 100 Square Foot) General Storage/Supply Room.
5. (130 to 150 Square Foot) General Storage/Supply Room.
6. (200 to 250 Square Foot) General Storage/Supply Room.
7. (400 Square Foot) General Storage/Supply Room.
8. (750 Square Foot) General Storage/Supply Room.

Project Storage

9. (144 to 200 Square Foot) Project Storage Room.
10. (400 to 700 Square Foot) Project Storage Room.

Equipment/Tool Storage

11. (100 to 150 Square Foot) Equipment/Tool Storage Room.
12. (300 Square Foot) Equipment/Tool Storage Room.
13. (500 Square Foot) equipment/Tool Storage Room.

Various Spaces

14. (150 Square Foot) Technology Student Association (TSA) Officer Office.
15. (200 Square Foot) Video Development/Editing Quiet Space.
16. (100 Square Foot) Server Closet.

Round Two Survey

The following 61 items are responses to Question 3: How should each instructional space be furnished? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Combination Computer/Lecture/Presentation Area

1. Student Computer Desks.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. Instructor Work Station/Desk.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. (28) Computer Style Chairs
4. Bookshelf Storage Case
5. Bulletin Board
6. Columned Notebook Racks
7. Combination CAD/Drafting Student Workstations
8. Combination CAD/Drafting Student Workstations with elevated monitors
9. Demonstration Station
10. Display Cabinet with Shelves
11. File Cabinet
12. General Drafting Tables
13. Lockable Storage Cabinet
14. Magazine Rack
15. Marker Board
16. Multimedia Cabinet
17. Printer Table.
18. Projection Screen
19. Projection Table
20. Rolling Adjustable Chairs
21. Student Chair—not on rollers

One Room Multipurpose Lab

22. Computer Tables
23. Design Pods with Conference table seating that accommodates 3 computers for or each 6 students.
24. Printer Table
25. Round Tables
26. Student Chairs
27. Teacher Desk

Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work

28. Activity storage cabinet wt/ tote trays
29. Adjustable stools
30. Built in cabinets and counter tops
31. Lockable storage/supply cabinets
32. Mobile material and activity cart
33. Portable standing height shop style workbenches
34. Printer table
35. Prototype and testing stations with adjustable stool
36. Standard height student worktables
37. Storage cabinet
38. Teacher command station
39. Work stations similar to modular tables

Prototyping/Material Processing

40. Activity Storage Cabinets wt/ Tote Trays
41. Built in cabinets and counter tops
42. Demonstration Table
43. Large Sink
44. Lockable Storage/Supply Cabinets

45. Mobile Material and Activity Cart
46. Standing height shop style workbenches
47. Stools
48. Storage Lockers for student projects.
49. Tool Storage Cabinet
50. Wall Mounted Tool Cabinets

Separate Classroom/Lecture Space—(Various Square Footages)

51. Book Storage Shelf
52. Bulletin Board
53. Durable theater seating with writing surface
54. Lockable Storage Cabinets
55. Multimedia Cabinet
56. Printer Table
57. Projection screen
58. Standard Student Desks
59. Teacher Workstation/Desk

Various Options

60. Built in countertops
61. Student Chair

Round Two Survey

The following 28 items are responses to Question 4: How should each support space be furnished? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Office

1. Teacher Desk.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. Book Storage Shelves.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Book/Multimedia storage cabinet
4. Built in counter workspace.
5. Lockable filing cabinet.
6. Lockable storage cabinet.

General Storage

7. Braced metal storage shelving.
8. Build in storage shelving.
9. Hanging hooks.
10. Large plastic see through bins.
11. Lockable storage cabinet.
12. Wire rack storage shelving.

Project Storage

13. Cage type access project storage.
14. Portable storage cabinets.
15. Portable wire shelving carts with plastic organizers.
16. Shelving units.
17. Wire rack storage shelving.

Equipment/Tool Storage

18. Braced metal storage shelving
19. Build in storage shelving.
20. Lockable storage cabinet.
21. Wire rack storage shelving.

Various Spaces

22. Technology Student Association (TSA) Officer Desk.
23. TSA book storage shelving.
24. TSA book/Multimedia storage cabinet
25. TSA built in counter workspace.
26. TSA Lockable filing cabinet.
27. TSA lockable storage cabinet.
28. Video Room built in counter top work space.

Round Two Survey

The following 27 items are responses to Question 5: What types of facility safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Eye wash station.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

2. Mounted First Aid Kit.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Clear Sight lines within Space for Student Supervision
4. Direct Exhaust Vents
5. Emergency Shut Off Switch
6. Evacuation Plans
7. Fire Extinguishers
8. Fire Resistant Trash Can
9. Flammable Storage Cabinet (Vented)
10. General Safety Rules Posted
11. Glass Sterilizing/Storage Cabinet
12. Hazardous Chemical Storage Cabinet (Vented)
13. High-Impact Block Walls
14. High-Impact Safety Glass in Divided Areas for Teacher Observation—
15. Kill Switches for Large Equipment
16. Machine Exhaust System
17. Machine Specific Safety Rules Posted at Each Machine
18. Paper Towel Rack
19. Quick Communication to Main Office
20. Regulated Air Connection
21. Restroom with Emergency Chemical Shower wt/floor Drain
22. Safety Signs
23. Sealed Concrete Floors
24. Shields on Machines
25. Sink with Soap Dispenser
26. VCT in production and Storage Areas to minimized Trip Hazards
27. Well Marked Safety Zone Areas

Round Two Survey

The following 16 items are responses to Question 6: What types of personal safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Eye Protection (Safety Glasses/Goggles).

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. Ear Protection.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Aprons
4. Chemical Aprons
5. Dust Masks
6. Face Shields
7. Gloves
8. Hair Pulled Back
9. Hard Hat
10. No Baggy Clothes
11. No Jewelry
12. No Long Sleeves
13. Protective Clothing
14. Respirators with Disposable Filters
15. Safety Glasses
16. Welding Safety Equipment

Round Two Survey

The following 59 items are responses to Question 7: What types of hand tools are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1.Claw Hammer

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. Ball Peen Hammer.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Adjustable Wrenches
4. Bar Clamps
5. Bench Brushes
6. Bolt Cutters
7. C-Clamps
8. Center Punch
9. Cold Chisels
10. Coping Saw
11. Crescent Wrench Set
12. Desoldering Iron
13. Divider
14. Electronics Vise
15. English Allen Wrenches
16. English Wrenches
17. Etching System
18. File Card
19. Flat Head Screwdrivers
20. Hack Saw
21. Hand Drill
22. Hand Seamer
23. Hex Wrenches
24. Hot Glue Guns
25. Level
26. Magnets
27. Metal Files
28. Metal Punch
29. Metric Allen Wrenches
30. Metric Wrenches
31. Nail Set
32. Phillips Screwdrivers
33. Plastic Mallet
34. Pliers
35. Pop Rivet Gun
36. Rubber Mallet
37. Sanding Blocks
38. Scissors
39. Scratch Awl
40. Scribes
41. Socket Set
42. Soldering Equipment
43. Spring Clamps
44. Staple Gun
45. Straight Edges
46. Tin Snips
47. Torque Wrenches
48. Triangles
49. Try Square
50. T-Squares
51. Tweezers
52. Twist Drills
53. Utility Knives
54. Wire Snips
55. Wire Strippers
56. Wood Chisels
57. Wood Files
58. Workbench Vises
59. Xacto Knives

Round Two Survey

The following 30 items are responses to Question 8: What types of hand held power tools are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Corded Hand Drill.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

2. Jig Saw.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Assorted Air Tools
4. Belt Sander
5. Buffer
6. Cordless Hand Drill
7. Dremel Tool
8. Electric Chisels
9. Grinder- with Sandpaper
10. Grinder- with Wheel
11. Hot Air Gun
12. Hot Wire Cutter
13. Laminate Trimmer Bits
14. Orbital Sanders
15. Palm Sander
16. Plastic Heat Strip
17. Plastics Welder
18. Pneumatic Nail Gun
19. Portaband (for metal Cutting)
20. Rotary Cutter
21. Router
22. Router
23. Router Bits
24. Saws All
25. Sheet Metal Shear
26. Skill Saw
27. Solder Pens
28. Solders Gun
29. Strip Heater
30. Wafer Doweling Tool

Round Two Survey

The following 41 items are responses to Question 9: What types of material processing equipment are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Table Saw.
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

2. Band Saw.
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. 3D Printer
4. Air Compressor
5. Autonomous Robot
6. CIM CELL with Robotic Arm, and Conveyor Belt
7. CNC Lathe
8. CNC Mill
9. CNC Router
10. Combo Belt/Disc Sander
11. Drill Press
12. Foam Cutter
13. Grinder/Wire Wheel Combo
14. Jointer
15. Laser Engraver
16. Metal Band Saw
17. Metal Brake
18. Metal Foot Shear
19. Metal Lathe
20. Metal Slip Rollers
21. MIG Welder
22. Oxy-Acetylene Unit
23. Planer
24. Plastic Injection Molder
25. Plastic Vacuum Forming Machine
26. Plastics Machine (multi-purpose)
27. Radial Arm Saw
28. Scroll Saw
29. Sheet Metal Tools
30. Sliding Compound Miter
31. Small MIG/Arc Welder Combo
32. Spindle Sander
33. Spot Welder
34. Table Top Band Saw
35. Table Top Drill Press
36. Table Top Table Saw
37. Thermo Fax Machine
38. Thermo former
39. TIG Welder
40. Vinyl Sign Machine
41. Wood Lathe

Round Two Survey

The following 32 items are responses to Question 10: What types of computer software are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. 3D Modeling/Design and Analytical Software.

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. Multimedia and Presentation Graphics Software

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. 2D CAD
4. 3D CAD
5. Animation
6. Architectural Design Software
7. Civil Design
8. Clip Art
9. Data Base
10. Desktop Publishing Software
11. Dictionary Software
12. Electronic Circuit Design Software
13. Electronics Training and Simulation
14. Engineering Training Software
15. Finite Element Modeling
16. Gaming
17. Internet Browser
18. MathCAD
19. Mechanical Workbench
20. Multimedia Generation and Podcast
21. Parallax Basic Stamp PLC Programming Software
22. PC Control Software
23. Sign or Banner Making Software
24. Software for Programming Robots
25. Spread Sheet
26. Spreadsheet
27. VEX Easy C PLC Programming Software
28. Video Editing Software
29. Web-Design
30. WestPoint Bridge Builder
31. Word Processing
32. Word Processing

Round Two Survey

The following 21 items are responses to Question 11: What types of audio visual equipment are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Cable TV Access

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

2. Computer Display-Touch Sensor

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Computer Projection System (LCD Projector and Projection Screen)
4. Convex Mirrors for student Supervision
5. Digital Camcorder
6. Digital Camera
7. Document Camera
8. DVD Player
9. Interactive or Smart Board
10. Interactive Tablet
11. Scanner
12. Scrolling Message Board
13. Stereo/CD player and Speakers with surround sound
14. TV Set
15. VCR
16. VCR/DVD Combo player-recorder
17. Web Access
18. Web Camera
19. Wireless Mouse
20. Wireless Pointer
21. Wireless Room Microphones and Speakers

Round Two Survey

The following 39 items are responses to Question 12: What types of measuring and testing devices are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Adjustable Triangles
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

2. Altimeter Gun
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Architects Scale
4. Computer Interfaced Materials/Structural Tester
5. Dial calipers
6. Drafting Tools
7. Engineering Scale
8. Fast Read Thermometers
9. Framing Square
10. GPS Tracking Device
11. Graduated Metal T-Squares
12. Hydrometer
13. Large Package Shipping Scale (600lbs)
14. Laser Level
15. Laser Tape Measure
16. Level
17. Light Guns
18. Measuring Tape
19. Metal Rulers
20. Meter Sticks
21. Metric Rulers
22. Micrometers
23. Multi-Meters
24. Oscilloscopes
25. PH Sensors
26. Postage Scale
27. Power Supplies
28. Pressure Sensors
29. Printer Scale
30. Protractors
31. Speed Square
32. Spring Scales
33. Stopwatches
34. Strain/Stress Gage
35. Temperature Sensors
36. Transit and Fulcrum
37. Triple Balance Beam with Weights
38. Wind Tunnel
39. Wood Rulers

Round Two Survey

The following 25 items are responses to Question 13: How many computers and computer related equipment are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Student Computer

1. (4) Student Laptops dedicated for TSA conference competitions

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. (6) Student Computers

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

Student Computers

3. (7) Computers
4. (15) Student Computers
5. (1) Computer per Student for a total of (28) student computers
6. (30) Student Computers
7. (45) Student Computers
8. (1) Dedicated Computer for Each CNC Machine (Robot, Mill, Lathe, and Laser Engraver) in addition to the student computers

Instructor Computers

10. (1) Instructor Computer
11. (1) Instructor Laptop
12. (2) Instructor Computers
13. (1) High Powered Demonstration Computer

Printers

14. (1) Black & White Laser Printer
15. (1) Color Laser Printer.
16. (1) Large Format CAD Printer/Plotter
17. (1-4) Inkjet Printer
18. (1-2) Scanner
19. (1) Fax

General Lab

20. (1) Classroom Phone
21 (1-2) Dedicated Phone Line
22. (1-2) Video Editing Stations
23. (1-2) Digital Still Cameras
24. (1-2) Camcorders
25. Networked lab with internet connection

Round Two Survey

The following 13 items are responses to Question 14: What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, and any other engineering related equipment if any are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Alternative Energy Systems Kits and Trainers

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

2. Automated Manufacturing Equipment

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Civil Engineering Trainer Kit
4. Electrical Motor Kits
5. Fischer Tech Interfacing
6. Hydraulics Trainer
7. Mechanisms Trainer
8. No Packaged Kits or Trainers are necessary
9. Pneumatics Trainer
10. Precision Measurement Trainer
11. Sensors and Transducers Kit
12. Variety of Electronics Basic Electricity Training Kits (Gibson Tech, Tronix, etc.)
13. Variety of Robotics Trainers (VEX, Lego Mindstorm, etc.)

Round Two Survey

The following 22 items are responses to Question 15: List any other item you feel is necessary for teaching engineering design concepts to high school students? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. 3 Hole Punch

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

2. Clear Tape

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Collaboration with Math and Science Teachers.
4. Colored Markers
5. Colored Pencils
6. Computer Paper
7. Construction Paper
8. Dry Erase Markers
9. Engineering Design Notebooks
10. Glue
11. Masking Tape
12. Office Supplies
13. Paper Cutter
14. Partnerships with local manufacturers, business, engineering firms, etc.
15. Play Dough
16. Reverse Engineering
17. Stapler
18. State Approved Curriculum
19. Tissue Paper
20. Turn Key Project Lead the Way Curriculum
21. Waste Paper Baskets
22. Water Fountain

APPENDIX G

ROUND TWO EMAIL

Thank you for your participation thus far in the DETERMINING THE INSTRUCTIONAL LABORATORY FACILITY REQUIREMENTS CRITICAL FOR INCLUDING ENGINEERING DESIGN IN THE ENGINEERING AND TECHNOLOGY EDUCATION FACILITY study! As you know, Round One is complete and I have compiled all the responses in the Round Two survey. In preparation for beginning Round Two, I am sending out this instructional email and link to Round Two Survey. Please find the link to Round Two: paste link

1. This Delphi study will determine the instructional laboratory facility requirements critical to teach engineering and technology in high school environments. To determine the essential features of these facilities, a coordinated group of educators and engineers will provide informed feedback about the requirements necessary for developing this type of learning environment. This study will develop consensus among the selected group of experts. The results will inform practitioners about the necessary steps to adequately equip high school engineering and technology laboratories.

2. Please complete Round Two survey by 7/9/09. As part of the survey you will be asked to indicate your level of agreement with the following statement for each survey item: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems. You will indicate your level of agreement/disagreement on a 6 point Likert scale.

3. This study is utilizing the Delphi method. This method dictates that in Round Two participants be given the Round One survey items again - which indicates the group response to each item. I acknowledge that this seems redundant. However, if you will bear with the process, the goal is to give you an opportunity to consider your choices again in light of the data. To assist you in this process I have attached an Microsoft Word file to this email with your responses to the Round One items. Please let me know if you have trouble opening the file, or any questions by contacting me via email or phone 404-604-5102.

Again, thank you very much for making this study possible!
Paul Camick

APPENDIX H

ROUND THREE SURVEY INSTRUMENT

Round Three Survey

The following items are responses to question 1 from Round 2: What Types of instructional spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

The Purpose of Round 3
Round 2 data (Mean, Median, Standard Deviation, and Inter-quartile Range) is included for Round 3. This will allow you to see how others in the sample group responded in Round 2. This data will give you a chance to revise your responses in light of the group response to the same items. Thus, the purpose of Round 3 will be to allow you, the experts, to revise your responses to match the other participants.

Combination Computer/Lecture/Presentation Area—(Various Square Footages)
1. 1000 to 1500 Square Feet (Data from Round 2: Mean=4.23, Median=5, SD=1.5055, IRQ=4-5)

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

2. 1800 to 2500 Square Feet (Data from Round 2: Mean=3.95, Median=4, SD=1.7313,IRQ=2.5-5.5)

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree

○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

One Room Multipurpose Lab

3. 1000 to 1200 Square Foot Multipurpose Room for entire lab- No other rooms necessary (Mean=2.61, Median=2, SD=1.7629, IRQ=1-4).

Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work—(Various Square Footages)

4. 250 Square Feet (Mean=1.62, Median=1, SD=.9500, IRQ=1-2
5. 1000 to 1200 Square Feet (Mean=3.86, Median=4, SD=1.3914,IRQ=3-5
6. 1800 to 2000 Square Feet (Mean=4.39, Median=4, SD=1.2420, IRQ=3.5-5)
7. 2400 to 2600 Square Feet (Mean=3.50, Median=4, SD=1.4381, IRQ=2-5)
8. New Item (1200-1800) Square Foot Space

Prototyping/Material Processing—(Various Square Footages)

9. 120 Square Feet (Mean=1.62, Median=1, SD=0.8438, IRQ=1-2)
10. 500 to 800 Square Feet (Mean=2.62, Median=3, SD=1.4302, IRQ=1-4)
11. 1000 to 1300 Square Feet(Mean=4.09, Median=4, SD=1.0999, IRQ=4-5)
12. 2000 to 2300 Square Feet (Mean=4.23, Median=4.5, SD=1.2035, IRQ=1.2035)
13. 2600 Square Feet (Mean=3.32, Median=3.5, SD=1.3944, IRQ=2-4)
14. 3000 Square Feet (Mean=2.33, Median=2, SD=1.0389, IRQ=2-3)
15. 3600 Square Feet (Mean=1.67, Median=2, SD=0.6424, IRQ=1-2)

Separate Classroom/Lecture Space—(Various Square Footages)

16. 500 Square Feet Classroom/Lecture Space with Raised Stadium Seating (Mean=3.00, Median=3, SD=1.6903, IRQ=2-5)
17. 250 to 500 Square Feet (Mean=2.55, Median=2.5, SD=1.2695, IRQ=2-3)
18. 800 to 1000 Square Feet(Mean=4.09, Median=5, SD=1.6658, IRQ=2.5-5)

Various Options

19. 250 Square Foot CNC/CIM/Rapid Prototyping Area (Mean=4.50, Median=5, SD=1.3399, IRQ=4-5)
20. 200 Square Foot Research/Resource Area (Mean=4.09, Median=4, SD=1.4420, IRQ=3.5-5)
21. 100 Square Foot Testing Lab (Mean=4.41, Median=5, SD=1.3369, IRQ=3.25-5)
22. 350 Square Foot Video Production Room (Mean=3.48, Median=4, SD=1.6116, IRQ=2-5)

Round Three Survey

The following items are responses to Question 2 from Round 2: What types of support spaces are necessary for incorporating engineering design in the technology education curriculum at the high school level for 28 students and 1 instructor? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Office

1. 70 to 100 Square Feet (Data from Round 2: Mean=3.64, Median=4, SD=1.6389, IRQ=2-5)

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

2. 130 to 150 Square Feet (Data from Round 2: Mean=4.62, Median=5, SD=1.3583, IRQ=4-5)

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. 200 Square Feet (Mean=2.91, Median=3, SD=1.4113, IRQ=2-4)

General Storage

4. 75 to 100 Square Feet (Mean=3.18, Median=3, SD=1.4345, IRQ=2-4.75)
5. 130 to 150 Square Feet (Mean=3.50, Median=4, SD=1.2340, IRQ=2.25-4)
6. 200 to 250 Square Feet (Mean=4.45, Median=5, SD=1.3048, IRQ=4-5)

Project Storage

7. 144 to 200 Square Feet (Mean=4.59, Median=5, SD=1.1143,IRQ=4-4)
8. 400 to 700 Square Feet (Mean=3.61, Median=4, SD=1.3101,IRQ=2.5-4)

Equipment/Tool Storage

9. 100 to 150 Square Feet (Mean=4.32, Median=5, SD=1.2929, IRQ=4-5)
10. 300 Square Feet (Mean=3.91, Median=4, SD=1.3111, IRQ=3-5)
11. 500 Square Feet (Mean=2.77, Median=2, SD=1.3461, IRQ=2-3.75)

Various Spaces

12. 150 Square Foot Technology Student Association (TSA) Officer Office (Mean=3.70, Median=4, SD=1.5724, IRQ=2.5-5)
13. 200 Square Foot Video Development/Editing Quiet Space (Mean=3.52, Median=4, SD=1.4407, IRQ=2-4.5)
14. 100 Square Foot Server Closet (Mean=3.59, Median=4, SD=1.7231, IRQ=2-5)

Round Three Survey

The following items are responses to Question 3 from Round 2: How should each instructional space be furnished? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Combination Computer/Lecture/Presentation Area

1. Bookshelf Storage Case (Data from Round 2: Mean=5.36, Median=5, SD=.4810, IRQ=5-6)
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

2. Bulletin Board (Data from Round 2: Mean=5.18, Median=5, SD=1.0285, IRQ=5-6)
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Columned Notebook Racks (Mean=3.90, Median=4, SD=1.3768, IRQ=4-5)
4. Combination CAD/Drafting Student Workstations (Mean=4.91, Median=5, SD=1.2398, IRQ=5-6)
5. Combination CAD/Drafting Student Workstations with elevated monitors (Mean=4.09, Median=5, SD=1.5641, IRQ=3-5)
6. Computer Style Chairs (Mean=4.52, Median=5, SD=1.1800, IRQ=4-5)
7. Demonstration Station (Mean=5.05, Median=5, SD=1.1069, IRQ=5-6)
8. Display Cabinet with Shelves (Mean=4.59, Median=5, SD=1.0295, IRQ=4-5)
9. File Cabinet (Mean=5.10, Median=5, SD=1.1508, IRQ=5-6)
10. General Drafting Tables (Mean=2.82, Median=2, SD=1.6414, IRQ=1.25-4)
11. Instructor Work Station/Desk (Mean=5.23, Median=5, SD=.5979, IRQ=5-6)
12. Lockable Storage Cabinet (Mean=5.45, Median=5, SD=.4979, IRQ=5-6)
13. Magazine Rack (Mean=3.90, Median=4, SD=1.3058, IRQ=3-5)
14. Marker Board (Mean=5.18, Median=5, SD=.7158, IRQ=5-6)
15. Multimedia Cabinet (Mean=4.82, Median=5, SD=1.0285, IRQ=5-5)
16. Printer Table (Mean=5.05, Median=5, SD=.8779, IRQ=5-5.75)
17. Projection Screen (Mean=5.41, Median=6, SD=.7781, IRQ=5-6)
18. Projection Table (Mean=4.70, Median=5, SD=1.4527, IRQ=4.75-6)
19. Rolling Adjustable Chairs (Mean=4.14, Median=4, SD=1.2539, IRQ=3.25-5)
20. Student Chair—not on rollers (Mean=3.91, Median=4, SD=1.5347, IRQ=3-5)
21. Student Computer Desk (Mean=4.23, Median=4, SD=1.1651, IRQ=3.25-5)

One Room Multipurpose Lab

22. Computer Tables (Mean=4.73, Median=5, SD=1.0523, IRQ=5-5)
23. Design Pods with Conference table seating that accommodates 3 computers for each 6 students (Mean=3.82, Median=4, SD=1.6689, IRQ=2-5)
24. Printer Table (Mean=5.09, Median=5, SD=.5961, IRQ=5-5)
25. Round Tables (Mean=3.91, Median=4, SD=1.3453, IRQ=3-5)
26. Student Chairs (Mean=5.27, Median=5, SD=0.5378, IRQ=5-6)
27. Teacher Desk (Mean=5.18, Median=5, SD=0.7158, IRQ=5-6)

Flexible Workspace/Project Staging/Materials Testing/Creative Problem Solving/Team Work

28. Activity storage cabinet wt/ tote trays (Mean=4.76, Median=5, SD=.08677, IRQ=4-5)
29. Adjustable stools (Mean=4.71, Median=5, SD=0.8248, IRQ=4-5)
30. Built in cabinets and counter tops (Mean=4.29, Median=5, SD=1.5164, IRQ=4-5)
31. Lockable storage/supply cabinets (Mean=5.14, Median=5, SD=0.6389, IRQ=5-5)
32. Mobile material and activity cart(Mean=4.71, Median=5, SD=1.302, IRQ=4-5)
33. Portable standing height shop style workbenches (Mean=4.38, Median=5, SD=1.2141, IRQ=4-5)
34. Printer table (Mean=4.60, Median=5, SD=1.1136, IRQ=4.5-5)
35. Prototype and testing stations with adjustable stool (Mean=4.57, Median=5, SD=1.1780, IRQ=4-5)
36. Standard height student worktables (Mean=4.65, Median=5, SD=1.1079, IRQ=4-5.25)
37. Storage cabinet (Mean=5.19, Median=5, SD=0.5871, IRQ=5-6)
38. Teacher command station (Mean=4.62, Median=5, SD=0.9500, IRQ=4-5)

39. Work stations similar to modular tables (Mean=3.25, Median=4, SD=1.5620, IRQ=2-5)

Prototyping/Material Processing

40. Activity Storage Cabinets wt/ Tote Trays (Mean=4.86, Median=5, SD=0.8144, IRQ=5-5)
41. Built in cabinets and counter tops (Mean=4.41, Median=5, SD=1.4032, IRQ=4-5)
42. Demonstration Table (Mean=4.77, Median=5, SD=1.2768, IRQ=5-5.75)
43. Large Sink (Mean=4.73, Median=5, SD=1.0947, IRQ=5-5)
44. Lockable Storage/Supply Cabinets (Mean=5.23, Median=5.5, SD=1.0415, IRQ=5-6)
45. Mobile Material and Activity Cart (Mean=4.82, Median=5, SD=0.7767, IRQ=4-5)
46. Standing height shop style workbenches (Mean=4.86, Median=5, SD=0.9674, IRQ=5-5)
47. Stools (Mean=4.59, Median=5, SD=1.8144, IRQ=4-5)
48. Storage Lockers for student projects (Mean=4.86, Median=5, SD=0.9193, IRQ=4-5.75)
49. Tool Storage Cabinet (Mean=5.36, Median=5, SD=0.6428, IRQ=5-6)
50. Wall Mounted Tool Cabinets (Mean=4.68, Median=5, SD=1.1827, IRQ=4-5)

Separate Classroom/Lecture Space—(Various Square Footages)

51. Book Storage Shelf (Mean=4.36, Median=5, SD=1.4938, IRQ=4-5)
52. Bulletin Board(Mean=4.64, Median=5, SD=1.5535, IRQ=5-5.75)
53. Durable theater seating with writing surface(Mean=3.41, Median=3, SD=1.8988, IRQ=1.25-5)
54. Lockable Storage Cabinets(Mean=4.10, Median=4, SD=1.3058, IRQ=4-5)
55. Marker Board(Mean=5.00, Median=5, SD=1.3484, IRQ=5-6)
56. Multimedia Cabinet(Mean=4.59, Median=5, SD=1.4666, IRQ=5-5)
57. Printer Table(Mean=4.41, Median=5, SD=1.4666, IRQ=4-5)
58. Projection screen(Mean=5.00, Median=5, SD=1.4800, IRQ=5-6)
59. Standard Student Desks(Mean=3.77, Median=5, SD=1.8570, IRQ=2-5)
60. Teacher Workstation/Desk(Mean=4.82, Median=5, SD=1.3361, IRQ=5-5.75)

Various Options

61. Built in countertops – Video Editing (Mean=3.29, Median=4, SD=1.5164, IRQ=2-5)

Round Three Survey

The following items are responses to Question 4 from Round 2: How should each support space be furnished? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Office

1. Book Storage Shelves (Data from Round 2: Mean=5.19, Median=5, SD=0.3927, IRQ=5-5)

   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

2. Book/Multimedia storage cabinet (Data from Round 2: Mean=4.76, Median=5, SD=0.9712, IRQ=4-5)

   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Built in counter workspace(Mean=3.57, Median=4, SD=1.4983, IRQ=2-5)
4. Lockable filing cabinet(Mean=5.05, Median=5, SD=0.7222, IRQ=5-5)
5. Lockable storage cabinet(Mean=5.43, Median=5, SD=0.4949, IRQ=5-6)
6. Teacher Desk(Mean=5.24, Median=5, SD=0.6835, IRQ=5-6)

General Storage

7. Braced metal storage shelving (Mean=4.77, Median=5, SD=1.0415, IRQ=4-5.75)
8. Build in storage shelving (Mean=4.45, Median=5, SD=1.3392, IRQ=4-5)
9. Hanging hooks (Mean=4.05, Median=4, SD=1.2961, IRQ=3-5)
10. Large plastic see through bins (Mean=4.86, Median=5, SD=0.6938, IRQ=5-5)
11. Lockable storage cabinet (Mean=4.95, Median=5, SD=0.9989, IRQ=5-6)
12. Wire rack storage shelving (Mean=4.23, Median=4.5, SD=1.2407, IRQ=3.25-5)

Project Storage

13. Cage type access project storage (Mean=3.68, Median=4, SD=1.3276, IRQ=3-5)
14. Portable storage cabinets (Mean=4.05, Median=4, SD=1.0900, IRQ=4-5)
15. Portable wire shelving carts with plastic organizers (Mean=4.05, Median=4, SD=1.2961, IRQ=3.25-5)
16. Shelving units (Mean=5.05, Median=5, SD=0.5622, IRQ=5-5)
17. Wire rack storage shelving (Mean=4.05, Median=5, SD=1.4917, IRQ=3-5)

Equipment/Tool Storage

18. Braced metal storage shelving (Mean=4.32, Median=5, SD=1.2572, IRQ=4-5)
19. Build in storage shelving (Mean=4.73, Median=5, SD=0.9621, IRQ=4-5)
20. Lockable storage cabinet (Mean=5.23, Median=5, SD=0.7343, IRQ=5-6)
21. Wire rack storage shelving (Mean=3.45, Median=3.5, SD=1.4054, IRQ=2-5)

Various Spaces

22. Technology Student Association (TSA) Officer Desk (Mean=3.67, Median=4 SD=1.5223, IRQ=2-5)
23. TSA book storage shelving (Mean=3.57, Median=4 SD=1.3653, IRQ=3-5)
24. TSA book/Multimedia storage cabinet (Mean=3.38, Median=4 SD=1.3619, IRQ=2-4)
25. TSA built in counter workspace (Mean=3.33, Median=4 SD=1.6134, IRQ=2-4)
26. TSA Lockable filing cabinet (Mean=3.68, Median=4 SD=1.5192, IRQ=2-5)
27. TSA lockable storage cabinet (Mean=3.77, Median=4 SD=1.4120, IRQ=4-5)
28. Video Room built in counter top work space (Mean=3.10, Median=3 SD=1.4110, IRQ=2-4)

Round Three Survey

The following items are responses to Question 5: What types of facility safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Clear Sight lines within Space for Student Supervision (Data from Round 2: Mean=5.86, Median=6, SD=0.3432, IRQ=6-6)

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Somewhat Disagree
- ◯ Somewhat Agree
- ◯ Agree
- ◯ Strongly Agree

2. Direct Exhaust Vents (Data from Round 2: Mean=4.86, Median=5.5, SD=1.4743, IRQ=4.25-6)

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Somewhat Disagree
- ◯ Somewhat Agree
- ◯ Agree
- ◯ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Emergency Shut Off Switch (Mean=5.55, Median=6, SD=0.8907, IRQ=5-6)
4. Evacuation Plans (Mean=5.77, Median=6, SD=0.44191, IRQ=6-6)
5. Eye Wash Station (Mean=5.36, Median=6, SD=0.9791, IRQ=5-6)
6. Fire Extinguishers (Mean=5.68, Median=6, SD=0.8732, IRQ=6-6)
7. Fire Resistant Trash Can (Mean=5.27, Median=6, SD=1.0082, IRQ=5-6)
8. Flammable Storage Cabinet (Vented)(Mean=5.09, Median=6, SD=1.3454, IRQ=5-6)
9. General Safety Rules Posted (Mean=5.73, Median=6, SD=0.4454, IRQ=5.25-6)
10. Glass Sterilizing/Storage Cabinet (Mean4.64, Median=5, SD=1.4630, IRQ=4-6)
11. Hazardous Chemical Storage Cabinet (Vented)(Mean=4.91, Median=6, SD=1.5929, IRQ=4.25-6)
12. High-Impact Block Walls (Mean=4.77, Median=5, SD=1.3795, IRQ=4.25-6)
13. High-Impact Safety Glass in Divided Areas for Teacher Observation (Mean=4.91, Median=5.5, SD=1.5048, IRQ=5-6)
14. Kill Switches for Large Equipment (Mean=5.55, Median=6, SD=1.0757, IRQ=5.25-6)
15. Machine Exhaust System (Mean=4.95, Median=5.5, SD=1.4917, IRQ=5-6)
16. Machine Specific Safety Rules Posted at Each Machine (Mean=5.27, Median=6, SD=1.2498, IRQ=5-6)
17. Mounted First Aid Kit (Mean=5.77, Median=6, SD=0.4191, IRQ=6-6)
18. Paper Towel Rack (Mean=5.14, Median=5, SD=0.7565, IRQ=5-6)
19. Quick Communication to Main Office (Mean=5.77, Median=6, SD=0.4191, IRQ=6-6)
20. Regulated Air Connection (Mean=5.18, Median=5, SD=0.8861, IRQ=5-6)
21. Restroom with Emergency Chemical Shower wt/floor Drain (Mean=4.00, Median=4, SD=1.3817, IRQ=3-5)
22. Safety Signs (Mean=5.73, Median=6, SD=0.4454, IRQ=5.25-6)
23. Sealed Concrete Floors (Mean=4.73, Median=5, SD=1.1355, IRQ=4-6)
24. Shields/Guards on Machines (Mean=5.64, Median=6, SD=1.0679, IRQ=6-6)
25. Sink with Soap Dispenser (Mean=5.32, Median=5, SD=0.6998, IRQ=5-6)
26. VCT in production and Storage Areas to minimized Trip Hazards (Mean=4.32, Median=5, SD=1.5192, IRQ=3.25-5)
27. Well Marked Safety Zone Areas (Mean=5.18, Median=6, SD=1.2298, IRQ=5-6)

Round Three Survey

The following items are responses to Question 6 from Round 2: What types of personal safety materials are necessary to provide a safe environment for all students working in the engineering and technology facility? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Aprons (Data from Round 2: Mean=3.86, Median=4, SD=1.3583, IRQ=3.25-5)

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. Dust Masks (Data from Round 2: Mean=4.68, Median=5, SD=1.2205,IRQ=4-5)

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Ear Protection (Mean=4.57, Median=5, SD=1.4662, IRQ=4-5)
4. Eye Protection (Safety Glasses/Goggles) (Mean=5.55, Median=6, SD=1.0757, IRQ=5.25-6)
5. Face Shields (Mean=4.36, Median=5, SD=1.3995, IRQ=4-5)
6. Gloves (Mean=3.91, Median=4, SD=1.5048, IRQ=3-5)
7. Hard Hat (Mean=3.18, Median=3, SD=1.1923, IRQ=3-4)
8. Protective Clothing (Mean=3.55, Median=4, SD=1.3392, IRQ=3-4)
9. Respirators with Disposable Filters (Mean=3.57, Median=4, SD=1.3997, IRQ=3-4)
10. Safety Glasses (Mean=5.64, Median=6, SD=1.0679, IRQ=6-6)
11. Welding Safety Equipment (Mean=4.50, Median=5, SD=1.6720, IRQ=3.25-6)

Round Three Survey

The following items are responses to Question 7: What types of hand tools are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Adjustable Wrenches (Data from Round 2: Mean=5.10, Median=5, SD=0.7681, IRQ=5-6)

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. Ball Peen Hammer (Data from Round 2: Mean=4.65, Median=5, SD=0.9631, IRQ=4-5)

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Bar Clamps (Mean=4.75, Median=5, SD=0.8874, IRQ=5-5)
4. Bench Brushes (Mean=4.74, Median=5, SD=0.9648, IRQ=4.5-5)
5. Bolt Cutters (Mean=4.00, Median=4, SD=1.0000, IRQ=3-5)
6. C-Clamps (Mean=5.05, Median=5, SD=0.7399, IRQ=5-5.25)
7. Center Punch (Mean=4.60, Median=5, SD=1.0677, IRQ=4-5)
8. Claw Hammer (Mean=4.85, Median=5, SD=0.9631, IRQ=4-5.25)
9. Cold Chisels (Mean=4.35, Median=4, SD=0.9097, IRQ=4-5)
10. Coping Saw (Mean=4.75, Median=5, SD=0.8729, IRQ=5-6)
11. Crescent Wrench Set (Mean=5.00, Median=5, SD=0.8729, IRQ=5-6)
12. Desoldering Iron (Mean=4.62, Median=5, SD=0.8985, IRQ=4-5)
13. Divider (Mean=4.43, Median=4, SD=1.0942, IRQ=4-5)
14. Electronics Vise (Mean=4.43, Median=5, SD=0.9548, IRQ=4-5)
15. English Allen Wrenches (Mean=4.90, Median=5, SD=0.8677, IRQ=5-5)
16. English Wrenches (Mean=5.00, Median=5, SD=0.6325, IRQ=5-5)
17. Etching System (Mean=3.33, Median=3, SD=1.2848, IRQ=2-4)
18. File Card (Mean=3.95, Median=4, SD=1.3619, IRQ=3-5)
19. Flat Head Screwdrivers (Mean=5.05, Median=5, SD=1.0900, IRQ=5-6)
20. Hack Saw (Mean=5.19, Median=5, SD=0.9571, IRQ=5-6)
21. Hand Drill (Mean=5.10, Median=5, SD=0.9209, IRQ=5-6)
22. Hand Seamer (Mean=3.95, Median=4, SD=1.1742, IRQ=3-5)
23. Hex Wrenches (Mean=4.95, Median=5, SD=0.9989, IRQ=4-6)
24. Hot Glue Guns (Mean=5.05, Median=5, SD=0.7222, IRQ=5-6)
25. Level (Mean=4.90, Median=5, SD=0.8677, IRQ=5-5)
26. Magnets (Mean=4.33, Median=4, SD=1.1269, IRQ=4-5)
27. Metal Files (Mean=4.95, Median=5, SD=0.8438, IRQ=4-6)
28. Metal Punch (Mean=4.76, Median=5, SD=0.9712, IRQ=4-5)
29. Metric Allen Wrenches (Mean=5.14, Median=5, SD=0.8330, IRQ=5-6)
30. Metric Wrenches (Mean=5.10, Median=5, SD=0.8109, IRQ=5-6)
31. Nail Set (Mean=4.67, Median=5, SD=0.8357, IRQ=4-5)
32. Phillips Screwdrivers (Mean=5.19, Median=5, SD=0.7940, IRQ=5-6)
33. Plastic Mallet (Mean=4.76, Median=5, SD=1.0191, IRQ=4-5)
34. Pliers (Mean=5.24, Median=5, SD=0.8190, IRQ=5-6)
35. Pop Rivet Gun (Mean=4.62, Median=5, SD=1.0900, IRQ=4-5)
36. Rubber Mallet (Mean=5.05, Median=5, SD=0.9500, IRQ=5-6)
37. Sanding Blocks (Mean=4.90, Median=5, SD=0.9712, IRQ=4-6)
38. Scissors (Mean=5.14, Median=5, SD=0.7095, IRQ=5-6)
39. Scratch Awl (Mean=4.52, Median=5, SD=1.2954, IRQ=4-5)
40. Scribes (Mean=4.62, Median=5, SD=1.3265, IRQ=4-6)
41. Socket Set (Mean=5.24, Median=5, SD=0.8109, IRQ=5-6)
42. Soldering Equipment (Mean=5.05, Median=5, SD=0.9500, IRQ=5-6)
43. Spring Clamps (Mean=5.00, Median=5, SD=0.9258 IRQ=5-6)
44. Staple Gun (Mean=4.86, Median=5, SD=1.8817, IRQ=4-6)
45. Straight Edges (Mean=5.29 Median=5, SD=0.6999, IRQ=5-6)
46. Tin Snips (Mean=4.86, Median=5, SD=1.0817, IRQ=4-6)
47. Torque Wrenches (Mean=4.86, Median=5, SD=1.1664, IRQ=4-6)
48. Triangles (Mean=4.90, Median=5, SD=0.8109, IRQ=4-5)

49. Try Square (Mean=4.86, Median=5, SD=0.9897, IRQ=4-6)
50. T-Squares (Mean=4.81, Median=5, SD=1.0519, IRQ=4-6)
51. Tweezers (Mean=4.81, Median=5, SD=0.7940, IRQ=4-5)
52. Twist Drills (Mean=4.81, Median=5, SD=1.0519, IRQ=4-6)
53. Utility Knives (Mean=5.14, Median=5, SD=0.7737, IRQ=5-6)
54. Wire Snips (Mean=5.00, Median=5, SD=1.0235, IRQ=4-6)
55. Wire Strippers (Mean=5.05, Median=5, SD=0.9989, IRQ=5-6)
56. Wood Chisels (Mean=4.62, Median=5, SD=0.9989, IRQ=4-5)
57. Wood Files (Mean=4.76, Median=5, SD=1.0191, IRQ=4-5)
58. Workbench Vises (Mean=4.90, Median=5, SD=0.9209, IRQ=5-5)
59. X-acto Knives (Mean=4.95, Median=5, SD=1.0900, IRQ=5-6)

Round Three Survey

The following items are responses to Question 8 from Round 2: What types of hand held power tools are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Assorted Air Tools (Data from Round 2: Mean=4.19, Median=5, SD=1.3669, IRQ=3-5)

   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

2. Belt Sander (Data from Round 2: Mean=4.76, Median=5, SD=1.0648, IRQ=4-6)

   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Buffer (Mean=3.86, Median=4, SD=1.1664, IRQ=4-4)
4. Corded Hand Drill (Mean=4.57, Median=5, SD=1.2178, IRQ=4-5)
5. Cordless Hand Drill (Mean=5.24, Median=5, SD=0.8109, IRQ=5-6)
6. Dremel Tool (Mean=4.86, Median=5, SD=0.9897, IRQ=5-5)
7. Electric Chisels (Mean=3.24, Median=3, SD=1.1086, IRQ=2-4)
8. Grinder- with Sandpaper (Mean=4.38, Median=5, SD=1.1742, IRQ=4-5)
9. Grinder- with Wheel (Mean=4.76, Median=5, SD=1.0191, IRQ=4-5)
10. Hot Air Gun (Mean=4.10, Median=4, SD=1.2207, IRQ=3.75-5)
11. Hot Wire Cutter (Mean=4.43, Median=5, SD=1.1780, IRQ=4-5)
12. Jig Saw (Mean=5.00 Median=5, SD=0.9759, IRQ=5-6)
13. Laminate Trimmer Bits (Mean=3.86, Median=4, SD=1.4892, IRQ=3-5)
14. Orbital Sanders (Mean=4.38, Median=5, SD=1.3965, IRQ=4-5)
15. Palm Sander (Mean=4.57, Median=5, SD=1.1369, IRQ=4-5)
16. Plastic Heat Strip (Mean=4.24, Median=5, SD=1.3058, IRQ=3-5)
17. Plastics Welder (Mean=4.10, Median=4, SD=1.1790, IRQ=4-5)
18. Pneumatic Nail Gun (Mean=3.67, Median=4, SD=1.6997, IRQ=2-5)
19. Portaband (for metal Cutting) (Mean=4.24, Median=5, SD=1.2688, IRQ=4-5)
20. Rotary Cutter (Mean=3.95, Median=5, SD=1.6176, IRQ=2-5)
21. Router (Mean=4.29, Median=5, SD=1.3502, IRQ=4-5)
22. Router Bits (Mean=4.29, Median=5, SD=1.3502, IRQ=4-5)
23. Saws All (Mean=4.29, Median=4, SD=1.1606, IRQ=345)
24. Sheet Metal Shear (Mean=4.29, Median=5, SD=1.5164, IRQ=4-5)
25. Skill Saw (Mean=4.67, Median=5, SD=0.8909, IRQ=4-5)
26. Solder Pens (Mean=4.52, Median=5, SD=1.2196, IRQ=4-5)
27. Solders Gun (Mean=4.76, Median=5, SD=0.8677, IRQ=4-5)
28. Strip Heater (Mean=4.38, Median=5, SD=1.2527, IRQ=4-5)
29. Wafer Doweling Tool (Mean=3.45, Median=3.5, SD=1.4654, IRQ=2-4.25)

Round Three Survey

The following items are responses to Question 9 from Round 2: What types of material processing equipment are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. 3D Printer (Data from Round 2: Mean=4.62, Median=5, SD=1.2901, IRQ=4-6)
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

2. Air Compressor (Data from Round 2: Mean=4.81, Median=5, SD=0.9060, IRQ=4-5)
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Autonomous Robot (Mean=4.10, Median=5, SD=1.3058, IRQ=3-5)
4. Band Saw (Mean=4.86, Median=5, SD=1.1249, IRQ=5-6)
5. CIM CELL with Robotic Arm, and Conveyor Belt (Mean=4.29, Median=5, SD=1.3145, IRQ=4-5)
6. CNC Lathe (Mean=4.52, Median=5, SD=1.0057, IRQ=4-5)
7. CNC Mill (Mean=4.52, Median=5, SD=1.0057, IRQ=4-5)
8. CNC Router (Mean=4.48, Median=5, SD=1.0519, IRQ=4-5)
9. Combo Belt/Disc Sander (Mean=4.57, Median=5, SD=1.2178, IRQ=4-5)
10. Drill Press (Mean=5.19, Median=5, SD=0.9060, IRQ=5-6)
11. Foam Cutter (Mean=4.81, Median=5, SD=1.1389, IRQ=5-5)
12. Grinder/Wire Wheel Combo (Mean=4.43, Median=5, SD=1.2936, IRQ=4-5)
13. Jointer (Mean=4.10, Median=4, SD=1.5089, IRQ=3-5)
14. Laser Engraver (Mean=4.00, Median=4, SD=1.4475, IRQ=3-5)
15. Metal Band Saw (Mean=4.62, Median=5, SD=1.0455, IRQ=4-5)
16. Metal Brake (Mean=4.14, Median=4, SD=1.2454, IRQ=3-5)
17. Metal Foot Shear (Mean=3.95, Median=4, SD=1.7313, IRQ=2.5-5.5)
18. Metal Lathe (Mean=4.00, Median=4, SD=1.2344, IRQ=3-5)
19. Metal Slip Rollers (Mean=3.76, Median=4, SD=1.3768, IRQ=3-5)
20. MIG Welder (Mean=3.95, Median=4, SD=1.3619, IRQ=3-5)
21. Oxy-Acetylene Unit (Mean=3.81, Median=4, SD=1.4349, IRQ=3-5)
22. Planer (Mean=3.71, Median=4, SD=1.4522, IRQ=3-5)
23. Plastic Injection Molder (Mean=4.10, Median=4, SD=1.1914, IRQ=4-5)
24. Plastic Vacuum Forming Machine (Mean=4.14, Median=4, SD=1.2066, IRQ=4-5)
25. Plastics Machine (multi-purpose) (Mean=4.24, Median=5, SD=1.3418, IRQ=4-5)
26. Radial Arm Saw (Mean=4.10, Median=5, SD=1.5401, IRQ=4-5)
27. Scroll Saw (Mean=4.48, Median=5, SD=1.0963, IRQ=4-5)
28. Sheet Metal Tools (Mean=4.48, Median=5, SD=1.1389, IRQ=4-5)
29. Sliding Compound Miter (Mean=4.38, Median=5, SD=1.2527, IRQ=4-5)
30. Small MIG/Arc Welder Combo (Mean=3.76, Median=4, SD=1.3418, IRQ=3-5)
31. Spindle Sander (Mean=3.52, Median=3, SD=1.2954, IRQ=3-5)
32. Spot Welder (Mean=3.81, Median=4, SD=1.4013, IRQ=3-5)
33. Table Saw (Mean=4.57, Median=5, SD=1.2936, IRQ=4-5)
34. Table Top Band Saw (Mean=4.71, Median=5, SD=1.1606, IRQ=5-5)
35. Table Top Drill Press (Mean=4.81, Median=5, SD=1.0519, IRQ=-5)
36. Table Top Table Saw (Mean=4.63, Median=5, SD=1.0863, IRQ=5-5)
37. Thermo Fax Machine (Mean=3.52, Median=4, SD=1.2581, IRQ=3-5)
38. Thermo former (Mean=3.70, Median=4, SD=1.2288, IRQ=3-5)
39. TIG Welder (Mean=3.19, Median=3, SD=1.4677, IRQ=2-5)
40. Vinyl Sign Machine (Mean=3.62, Median=4, SD=1.3965, IRQ=2-5)
41. Wood Lathe (Mean=3.19, Median=3, SD=1.4013, IRQ=2-5)

Round Three Survey

The following items are responses to Question 10 from Round 2: What types of computer software are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. 2D CAD (Data from Round 2: Mean=4.29, Median=5, SD=1.3851, IRQ=3-5)

   - ○ Strongly Disagree
   - ○ Disagree
   - ○ Somewhat Disagree
   - ○ Somewhat Agree
   - ○ Agree
   - ○ Strongly Agree

2. 3D Modeling/Design and Analytical Software (Data from Round 2: Mean=5.38, Median=6, SD=0.7854, IRQ=5-6)

   - ○ Strongly Disagree
   - ○ Disagree
   - ○ Somewhat Disagree
   - ○ Somewhat Agree
   - ○ Agree
   - ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Animation (Mean=4.71, Median=5, SD=1.1188, IRQ=4-5)
4. Architectural Design Software (Mean=4.90, Median=5, SD=0.9209, IRQ=5-5)
5. Civil Design (Mean=4.14, Median=4, SD=0.9404, IRQ=4-5)
6. Classroom Management and Supervision Software (Mean=4.62, Median=5, SD=1.2527, IRQ=4-5)
7. Clip Art (Mean=4.43, Median=5, SD=1.0498, IRQ=4-5)
8. Data Base (Mean=4.71, Median=5, SD=0.8248, IRQ=4-5)
9. Desktop Publishing Software (Mean=4.90, Median=5, SD=0.9712, IRQ=5-5)
10. Dictionary Software (Mean=3.76, Median=4, SD=1.2688, IRQ=3-5)
11. Electronic Circuit Design Software (Mean=4.90, Median=5, SD=1.1086, IRQ=5-6)
12. Electronics Training and Simulation (Mean=4.71, Median=5, SD=0.9828, IRQ=4-5)
13. Engineering Training Software (Mean=5.00, Median=5, SD=0.7071, IRQ=5-5)
14. Finite Element Modeling (Mean=4.35, Median=4, SD=1.1079, IRQ=4-5)
15. Gaming Design and Development (Mean=3.90, Median=4, SD=1.3418, IRQ=3-5)
16. Internet Browser (Mean=5.57, Median=6, SD=10.4949, IRQ=5-6)
17. MathCAD (Mean=4.25, Median=4, SD=1.0897, IRQ=4-5)
18. Mechanical Workbench (Mean=4.35, Median=4.5, SD=1.1079, IRQ=4-5)
19. Multimedia and Presentation Graphics Software (Mean=5.24, Median=5, SD=0.6835, IRQ=5-6)
20. Multimedia Generation and Podcast (Mean=4.52, Median=5, SD=1.0057, IRQ=4-5)
21. Parallax Basic Stamp PLC Programming Software (Mean=4.25, Median=5, SD=1.4098, IRQ=4-5)
22. PC Control Software (Mean=4.60, Median=5, SD=0.8000, IRQ=4-5)
23. Sign or Banner Making Software (Mean=3.95, Median=4, SD=1.1169, IRQ=3-5)
24. Software for Programming Robots (Mean=4.95, Median=5, SD=1.1169, IRQ=5-6)
25. Spreadsheet (Mean=5.24, Median=5, SD=0.6835, IRQ=5-6)
26. VEX Easy C PLC Programming Software (Mean=4.60, Median=5, SD=1.1136, IRQ=4-5)
27. Video Editing Software (Mean=4.14, Median=5, SD=1.4892, IRQ=3-5)
28. Web-Design (Mean=4.35, Median=5, SD=1.2359, IRQ=4-5)
29. WestPoint Bridge Builder (Mean=4.81, Median=5, SD=0.7315, IRQ=4-5)
30. Word Processing (Mean=5.52, Median=6, SD=0.4994, IRQ=5-6)

Round Three Survey

The following items are responses to Question 11 from Round 2: What types of audio visual equipment are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Cable TV Access (Mean=4.23, Median=4, SD=1.1254, IRQ=4-5)

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

2. Computer Display-Touch Sensor (Mean=3.90, Median=4, SD=1.1914, IRQ=3-5)

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Somewhat Agree
- Agree
- Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Computer Projection System (LCD Projector and Projection Screen) (Mean=5.41, Median=5.5, SD=0.7173, IRQ=5-6)
4. Convex Mirrors for student Supervision (Mean=3.95, Median=4, SD=1.3619, IRQ=3-5)
5. Digital Camcorder (Mean=5.00, Median=5, SD=0.6901, IRQ=5-5)
6. Digital Camera (Mean=4.86, Median=5, SD=1.0817, IRQ=5-5)
7. Document Camera (Mean=3.90, Median=4, SD=1.3768, IRQ=3-5)
8. DVD Player (Mean=4.81, Median=5, SD=1.0963, IRQ=5-5)
9. Interactive or Smart Board (Mean=4.64, Median=5, SD=1.0679, IRQ=4-5)
10. Interactive Tablet (Mean=4.33, Median=4, SD=1.1269, IRQ=4-5)
11. Scanner (Mean=4.95, Median=5, SD=0.7854, IRQ=5-5)
12. Scrolling Message Board (Mean=3.52, Median=4, SD=1.1389, IRQ=3-4)
13. Stereo/CD player and Speakers with surround sound (Mean=3.90, Median=4, SD=1.1086, IRQ=4-5)
14. TV Set (Mean=4.19, Median=5, SD=1.2954, IRQ=4-5)
15. VCR (Mean=3.25, Median=3.5, SD=1.5772, IRQ=2-5)
16. VCR/DVD Combo player-recorder (Mean=4.67, Median=5, SD=1.2084, IRQ=4-5)
17. Web Access (Mean=5.45, Median=5, SD=0.4979, IRQ=5-6)
18. Web Camera (Mean=4.60, Median=5, SD=1.2806, IRQ=4-5.25)
19. Wireless Mouse (Mean=4.75, Median=5, SD=1.2600, IRQ=4-6)
20. Wireless Pointer (Mean=4.30, Median=5, SD=1.3077, IRQ=3.75-5)
21. Wireless Room Microphones and Speakers (Mean=4.25, Median=4, SD=1.1347, IRQ=4-5)

Round Three Survey

The following items are responses to Question 12 from Round 2: What types of measuring and testing devices are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Adjustable Triangles (Data from Round 2: Mean=4.62, Median=5, SD=0.9989, IRQ=4-5)
   - ○ Strongly Disagree
   - ○ Disagree
   - ○ Somewhat Disagree
   - ○ Somewhat Agree
   - ○ Agree
   - ○ Strongly Agree

2. Altimeter Gun (Data from Round 2: Mean=4.29, Median=5, SD=1.2778, IRQ=3-5)
   - ○ Strongly Disagree
   - ○ Disagree
   - ○ Somewhat Disagree
   - ○ Somewhat Agree
   - ○ Agree
   - ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Architects Scale (Mean=5.00, Median=5, SD=0.9258, IRQ=5-6)
4. Computer Interfaced Materials/Structural Tester (Mean=3.95, Median=4, SD=0.7854, IRQ=4-4)
5. Dial calipers (Mean=5.05, Median=5, SD=0.7222, IRQ=5-5)
6. Drafting Tools (Mean=4.67, Median=5, SD=1.1269, IRQ=4-5)
7. Engineering Scale (Mean=5.14, Median=5, SD=0.7737, IRQ=5-6)
8. Fast Read Thermometers (Mean=4.67, Median=5, SD=0.9428, IRQ=4-5)
9. Framing Square (Mean=4.48, Median=4, SD=0.9571, IRQ=4-5)
10. GPS Tracking Device (Mean=4.24, Median=4, SD=1.2307, IRQ=4-5)
11. Graduated Metal T-Squares (Mean=4.24, Median=4, SD=1.2307, IRQ=4-5)
12. Hydrometer (Mean=4.10, Median=5, SD=1.1508, IRQ=3-5)
13. Large Package Shipping Scale (600lbs) (Mean=3.57, Median=4, SD=1.3653, IRQ=3-5)
14. Laser Level (Mean=4.33, Median=4, SD=1.1269, IRQ=4-5)
15. Laser Tape Measure (Mean=4.29, Median=4, SD=1.1606, IRQ=4-5)
16. Level (Mean=4.67, Median=5, SD=1.0389, IRQ=4-5)
17. Light Guns (Mean=3.95, Median=4, SD=1.0712, IRQ=3-5)
18. Measuring Tape (Mean=5.29, Median=5, SD=0.5471, IRQ=5-6)
19. Metal Rulers (Mean=5.10, Median=5, SD=1.0191, IRQ=5-6)
20. Meter Sticks (Mean=5.24, Median=5, SD=0.4259, IRQ=5-5)
21. Metric Rulers (Mean=5.24, Median=5, SD=0.4259, IRQ=5-5)
22. Micrometers (Mean=5.25, Median=5, SD=0.6982, IRQ=5-6)
23. Multi-Meters (Mean=5.19, Median=5, SD=0.7940, IRQ=5-6)
24. Oscilloscopes (Mean=4.57, Median=5, SD=1.1369, IRQ=4-5)
25. PH Sensors (Mean=4.14, Median=4, SD=1.2066, IRQ=3-5)
26. Postage Scale (Mean=4.15, Median=4.5, SD=1.4239, IRQ=3.75-5)
27. Power Supplies (Mean=5.00, Median=5, SD=0.8367, IRQ=4.75-6)
28. Pressure Sensors (Mean=4.62, Median=5, SD=1.3619, IRQ=4-6)
29. Printer Scale (Mean=4.20, Median=5, SD=1.4697, IRQ=3-5)
30. Protractors (Mean=5.00, Median=5, SD=0.7746, IRQ=5-5.25)
31. Speed Square (Mean=3.90, Median=4, SD=1.5133, IRQ=3-5)
32. Spring Scales (Mean=4.62, Median=5, SD=1.2901, IRQ=4-5)
33. Stopwatches (Mean=5.05, Median=5, SD=0.8438, IRQ=5-6)
34. Strain/Stress Gage (Mean=5.00, Median=5, SD=0.9759, IRQ=5-6)
35. Temperature Sensors (Mean=4.95, Median=5, SD=1.0455, IRQ=5-6)
36. Transit and Fulcrum (Mean=4.48, Median=4, SD=1.0519, IRQ=4-5)
37. Triple Balance Beam with Weights (Mean=4.62, Median=5, SD=1.0900, IRQ=4-5)
38. Wind Tunnel (Mean=4.43, Median=5, SD=1.3299, IRQ=4-5)
39. Wood Rulers (Mean=4.05, Median=4.5, SD=1.5322, IRQ=3-5)

Round Three Survey

The following items are responses to Question 13 from Round 2: How many computers and computer related equipment are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

Student Computer

1. (6) Student Computers (Data from Round 2: Mean=1.95, Median=1, SD=1.2141, IRQ=1-3)
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree
2. (7) Student Computers (Data from Round 2: Mean=2.10, Median=2, SD=1.4110, IRQ=1-3)
   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

Student Computers

3. (15) Student Computers (Mean=3.14, Median=3, SD=1.6983, IRQ=2-4)
4. Computer Per Student for a total of (28) student computers (Mean=5.09, Median=6, SD=1.2026, IRQ=4.25-6)
5. (30) Student Computers (Mean=4.00, Median=5, SD=1.5736, IRQ=3-5)
6. (45) Student Computers (Mean=2.00, Median=2, SD=1.1402, IRQ=1-3)

Other Lab Computers

7. Dedicated Computer for Each CNC Machine (Robot, Mill, Lathe, and Laser Engraver) in addition to the student computers (Mean=4.65, Median=5, SD=1.4239, IRQ=4-6
8. (4) Student Laptops dedicated for TSA conference competitions (Mean=4.40, Median=5, SD=1.4967, IRQ=3.75-6)

Printers

9. (1) Black & White Laser Printer (Mean=5.15, Median=5, SD=0.7921, IRQ=4.75-6)
10. (1) Color Laser Printer (Mean=5.33, Median=5, SD=0.7766, IRQ=5-6)
11. (1) Fax (Mean=3.53, Median=3, SD=1.3126, IRQ=3-4)
12. (1) Large Format CAD Printer/Plotter (Mean=5.10, Median=5, SD=1.2307, IRQ=5-6)
13. (1-4) Inkjet Printer (Mean=3.95, Median=4, SD=1.6050, IRQ=2.5-5)

General Lab

14. Networked lab with internet connection (Mean=5.67, Median=6, SD=0.5634, IRQ=5-6)
15. (1) Classroom Phone (Mean=5.29, Median=6, SD=0.9828, IRQ=5-6)
16. (1-2) Camcorders (Mean=5.00, Median=5, SD=0.8729, IRQ=4-6)
17. (1-2) Dedicated Phone Line (Mean=4.57, Median=5, SD=1.3299, IRQ=4-6)
18. (1-2) Digital Still Cameras (Mean=5.14, Median=5, SD=0.7737, IRQ=5-6)
19. (1-2) Scanner (Mean=5.14, Median=5, SD=0.7737, IRQ=5-6)
20. (1-2) Video Editing Stations (Mean=3.95, Median=4, SD=1.3619, IRQ=3-5)

Instructor Computers

21. (1) Instructor Computer (Mean=5.43, Median=6, SD=0.8492, IRQ=5-6)
22. (2) Instructor Computers (Mean=5.40, Median=6, SD=0.9695, IRQ=4.75-6)
23. (1) Instructor Laptop (Mean=4.26, Median=5, SD=1.5163, IRQ=3.5-5)
24. (1) High Powered Demonstration Computer (Mean=4.90, Median=5, SD=1.0909, IRQ=4-6)

Round Three Survey

The following items are responses to Question 14 from Round 2: What types of engineering related kits, robotics kits, electronics trainers, automated manufacturing packages, and any other engineering related equipment if any are necessary? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. Alternative Energy Systems Kits and Trainers (Data from Round 2: Mean=4.10, Median=4, SD=1.5089, IRQ=3-5)

   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

2. Automated Manufacturing Equipment (Data from Round 2: Mean=4.24, Median=5, SD=1.4110, IRQ=4-5)

   - Strongly Disagree
   - Disagree
   - Somewhat Disagree
   - Somewhat Agree
   - Agree
   - Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Civil Engineering Trainer Kit (Mean=3.76, Median=4, SD=1.3768, IRQ=3-5)
4. Electrical Motor Kits (Mean=4.05, Median=4, SD=1.3965, IRQ=4-5)
5. Fischer Tech Interfacing (Mean=3.65, Median=4, SD=1.3519, IRQ=2.75-4.25)
6. Hydraulics Trainer (Mean=3.71, Median=4, SD=1.5779, IRQ=2-5)
7. Mechanisms Trainer (Mean=3.76, Median=4, SD=1.5707, IRQ=2-5)
8. No Packaged Kits or Trainers are necessary (Mean=3.24, Median=3, SD=1.7431, IRQ=2-5)
9. Pneumatics Trainer (Mean=3.74, Median=3, SD=1.6493, IRQ=2-5)
10. Precision Measurement Trainer (Mean=3.90, Median=4, SD=1.5089, IRQ=3-5)
11. Sensors and Transducers Kit (Mean=4.29, Median=5, SD=1.4846, IRQ=4-5)
12. Variety of Electronics Basic Electricity Training Kits (Gibson Tech, Tronix, etc.) (Mean=4.62, Median=5, SD=1.3965, IRQ=4-6)
13. Variety of Robotics Trainers (VEX, Lego Mindstorm, etc.) (Mean=4.71, Median=5, SD=1.4190, IRQ=4-6)

Round Three Survey

The following items are responses to Question 15 from Round 2: List any other item you feel is necessary for teaching engineering design concepts to high school students? For each item, please indicate your level of agreement with the following statement: This item is a critical and necessary component of an engineering and technology education facility which is designed to equip secondary (high school) students to understand, manage, and solve technological problems.

1. 3 Hole Punch (Data from Round 2: Mean=4.90, Median=5, SD=0.8109, IRQ=4-5)

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

2. Clear Tape (Data from Round 2: Mean=5.14, Median=5, SD=0.6389, IRQ=5-6)

- ○ Strongly Disagree
- ○ Disagree
- ○ Somewhat Disagree
- ○ Somewhat Agree
- ○ Agree
- ○ Strongly Agree

Note – the remaining items in this survey instrument have the Likert scale removed to make this document more readable.

3. Collaboration with Math and Science Teachers (Mean=5.52, Median=6, SD=0.6633, IRQ=5-6)
4. Colored Markers (Mean=5.10, Median=5, SD=0.7499, IRQ=5-6)
5. Colored Pencils (Mean=4.81, Median=5, SD=0.9060, IRQ=4-5)
6. Computer Paper (Mean=5.38, Median=5, SD=0.5754, IRQ=5-6)
7. Construction Paper (Mean=4.76, Median=5, SD=1.1914, IRQ=4-6)
8. Dry Erase Markers (Mean=5.43, Median=5, SD=0.4949, IRQ=5-6)
9. Engineering Design Notebooks (Mean=5.52, Median=6, SD=0.5871, IRQ=5-6)
10. Glue (Mean=5.19, Median=5, SD=0.7315, IRQ=5-6)
11. Masking Tape (Mean=5.19, Median=5, SD=0.6633, IRQ=5-6)
12. Office Supplies (Mean=5.45, Median=5, SD=0.4975, IRQ=5-6)
13. Paper Cutter (Mean=5.19, Median=5, SD=0.7315, IRQ=5-6)
14. Partnerships with local manufacturers, business, engineering firms, etc (Mean=5.52, Median=6, SD=0.4994, IRQ=5-6)
15. Play Dough (Mean=3.48, Median=4, SD=1.4349, IRQ=2-4)
16. Reverse Engineering (Mean=4.86, Median=5, SD=0.9404, IRQ=4-6)
17. Stapler (Mean=5.24, Median=5, SD=0.6835, IRQ=5-6)
18. State Approved Curriculum (Mean=4.76, Median=5, SD=1.3768, IRQ=4-6)
19. Tissue Paper (Mean=4.48, Median=5, SD=0.9060, IRQ=4-5)
20. Turn Key Project Lead the Way Curriculum (Mean=3.95, Median=5, SD=1.9875, IRQ=1-6)
21. Waste Paper Baskets (Mean=5.43, Median=6, SD=0.6598, IRQ=456)
22. Water Fountain (Mean=4.27, Median=5, SD=1.5428, IRQ=4-5)
23. New Item-Recycle Bin

APPENDIX I

ROUND THREE EMAIL

Hello All,
It is time to complete the third and final round of the study. The link to the survey is:
http://www.surveymonkey.com/s.aspx?sm=h2DAgwaeMpWUlpaRlE7bJw_3d_3d
The survey should take you no longer than 30 to 45 minutes. Please complete the survey by August 31, if not sooner. This will allow me to finish and graduate this December (hopefully).
I truly appreciate your continued participation- you all have been great!
Attached you will find an official letter and raw data from round 2 (excel file). In addition below you will find the purpose of Round 3. Please take the time to read this over so you develop an understanding of what is expected from you in the final round.

The Purpose of Round 3

Round 3 data (Mean, Median, Standard Deviation, and Inter-quartile Range) will be analyzed by you, the expert participants, for each item listed for this round. This will allow you to see how others in the sample group responded in round 2. This will give you a chance to revise your responses in light of the group response to the same items. Thus, the purpose of Round 3 will be to allow you, the experts, to revise your responses to match the other participants. Of course, if you feel strongly against what the group responses are-- continue to score that item the way you see them. In addition there is a space for you to add comments on any response you feel you need to explain.

Example:
Mean=1.62 Median=1 SD=0.8438 IRQ=1-2

Explanation- On a scale from 1 to 6, the average of all participant responses was 1.62 (this would suggest a low level of need). The middle of all distribution is 1 (of 23 participants the middle value is 1- suggesting a low level of need). Standard Deviation: Add .8438 to 1.62, and subtract .8438 to 1.62 the majority of responses will fall within that range-telling us that most are rating the item between 1 and 2 on a scale from 1 to 6 (evidence of low need). IRQ of 1-2 is telling us that 50% of the data fall between 1 and 2 on a scale from 1 to 6. This would suggest that there is a fair amount of consensus that this particular item is not needed/critical. An IRQ of 1-4 would have suggested that there is little consensus with this item.

**From this data example you would either agree or disagree. If you agree with the group you would select the Median (or below) (in this example 1 or strongly disagree). If you disagree with the group you would continue to score as you see the item should be (scale of 1 to 6).

Another example is : An item has a Median of 5 (Agree) and you agree with the group data you then would mark that item as 5 or 6 – (Agree, or Strongly Agree) depending on how strongly you agree. Again, if you disagree, you would continue to score as you see the tem should be (scale of 1 to 6).

Statistical Definitions

Mean
The mean is what is commonly called the average: The mean is the sum of all the scores divided by the number of scores.

Median
The median is the middle of a distribution: half the scores are above the median and half are below the median. The median is less sensitive to extreme scores than the mean and this makes it a better measure than the mean for highly skewed distributions.

Standard Deviation (SD)
If you add one standard deviation to your mean and subtract one standard deviation from your mean, you should find that a majority of your scores fall between those two numbers. If you add and subtract 2 standard deviations you should find that nearly all of your scores will fall between those two numbers. Statisticians have found this fact to be very useful, and in many cases they use this property to determine the probability of a given data point occurring. This allows them to determine the verity or falseness of hypotheses.

Inter-quartile range (IRQ)
The inter-quartile range (IQR) is the distance between the 75th percentile and the 25th percentile. The IQR is essentially the range of the middle 50% of the data. Because it uses the middle 50%, the IQR is not affected by outliers or extreme values.

APPENDIX J

FINAL REPORT

Engineering Design Focused Technology Education Program Support Materials

Facility Design Planning Guide

2010

Technology Education

Program Support Materials

Facility Design and Implementation

Table of Contents

RESEARCH

Rational/Need

Engineering design as a curriculum focus for technology education is gaining wide expectance by many in the field of technology education (Asunda & Hill, 2007; Dearing & Daugherty, 2004; Gattie & Wicklein, 2007; Lewis, 2004, 2005; Wicklein, 2006). This will require attention to determine the technology education facility requirements that meet the changing focus of curriculum. Daugherty, Klenke, and Neden, (2008) contend “most technology education facilities continue to operate well past the planned life span of classroom and laboratory spaces” (p. 20). It is imperative that professionals in the field of technology education including teachers, administrators, and faculty at teacher preparation institutions have access to research based information designed for making decisions regarding the implementation of facilities that support engineering design focused curriculum.

Current Laboratory Trends for Technology Education

Technology education courses that focus on engineering design as a curriculum component are essentially laboratory courses in which students are expected to design, build, and test prototypes (NCTL, 2008). While students can learn a great deal from textbooks and discussion sessions, laboratory experiences are necessary for a greater understanding of what engineering truly is (NCTL, 2008). As with any curriculum development process, there is a need to identify the purpose of the curriculum, the resources, and the societal needs, and then to outline the instructional content that will meet these needs (DeVore, 1991). Without the curriculum design firmly in place, teachers and administrators have nothing to help guide them with the ordering of new equipment, or remodeling or updating existing facilities. This practice runs the risk of spending difficult to obtain money in a wasteful manner. Facilities must be designed to meet curriculum needs. Before equipment, software, textbooks, etc, are purchased they must first meet the criteria for enhancing and supporting the stated curriculum of the program (Daugherty et al., 2008).

Daugherty et al. (2008) suggest that "all contemporary technology education facility changes should be based on an alignment with *Standards for Technological Literacy* (SLT)". The goal of standards based laboratory instruction is to provide students with hands-on learning experiences that utilize constructivist learning techniques. Although these standards are key to understanding the essential components of an effective technology education laboratory, there is little research too support such a claim (McCrory, 1987). Daugherty et al. (2008) write:

> With the advent of Standards for Technological Literacy and current curricular trends, consistency of instructional facilities is a crucial next step in establishing the field both politically and socially. In order to standardize technology education, it is necessary to standardize the essential elements within the technology education laboratory. This homogeny not only insures a consistent educational delivery platform across the county, it will help define the profession within the modern school environment. (p. 22)

Daugherty et al. (2008) describe the model technology education facility as including four distinct learning environments:

1. The presentation center, designed for instructor-led presentation, multimedia presentations, student presentations, and for the exploration of technological concepts and ideas.

2. The Communication Center, designed to allow for research and development, internet research, and individual and group investigations and activity.
3. The resource/testing center, designed to give space for group engineering design, problem solving, cooperative learning, and other group interactions.
4. The fabrication center, designed for inventing and innovating engineering models, prototypes, and mock-ups.

Daugherty et al. (2008) believe that technology education facilities should “provide space for the introduction, exploration, engagement, and expansion of technological ideas, concepts, and principles” (p. 22).

Burrows (2008) conducted a study to gather information from practicing engineers about the activities, skills, and equipment necessary for teaching engineering and technology at the high school level. He concluded that this type of facility must be separated into three basic areas by percent of overall lab space available. His conclusion was 29.29% of the overall lab space should be dedicated to lecture and seating, 35.71% to computers and testing equipment, and 35% to prototype development (p.31).

Constructivism Approach to Learning

The educational theory known as constructivism is based on the foundational works of Dewey, Piaget, and Vygotsky (Bransford, Brown, & Cocking, 2000). The basic philosophy is, “people construct new knowledge and understanding based on what they already know and believe” (Bransford et al., 2000 p. 10). Wankat (2002) writes “learning is done by the students, not by the professor, learning is always based on what the students know and believe” (p. 3). Jacobson and Wilensky (2006) suggest that young learners can handle complex systems thinking at all levels of education, stating, “a central tenet of constructivist or constructionist learning approach is that a learner is actively constructing new understanding, rather than passively receiving and absorbing facts" (p. 22). Building on what people already know is an active process requiring a number of steps (Bransford et al., 2000). Wankat (2002) list 3 basic steps to build upon what people already know.

> First, students need to be motivated to spend the time and energy necessary to build or rebuild a knowledge structure. Second, students need to learn correct facts. Third, the framework of the knowledge structure needs to be organized in a way that helps the students retrieve and apply the knowledge (p. 4).

Jacobson and Wilensky (2006) believe that this method of teaching is more interesting, engaging, and motivating for students. They contend that students increase their understanding of complex systems by solving authentic problems within a cooperative learning environment.

Wanket (2002) adds that to learn efficiently, people must use meta-cognition to control their own learning processes. Meta-cognition requires students to first make sense of what concept is being taught by relating it back to their own knowledge structure. Second, students will need to be able to look inward for self-assessment. They will need to be able to self-assess their learning to know if they understand the material correctly. Last, students must reflect on what they learned, by determining what learning approaches worked during the learning process. Bradford et al., (2000) contends that the ideal classroom environment for a constructivist approach is a classroom that includes:

> Learn centered--pay attention to the students' preconceptions, skills and attitudes;
> Knowledge centered--pay attention to the subject, student understanding and mastery;
> Assessment centered--use frequent formative assessment by both the teacher and the student to monitor progress;

> Community centered--The context of learning is important. Combined argumentation plus cooperation enhances cognitive development. (pp. 133-149)

Similar ideas have been expressed by Dyer, Reed, and Berry (2006). They cited Crawford and the Center for Occupation Research and Development who list five key strategies to actively engaging students in a constructivist approach to teaching in exemplar classrooms. These five strategies are:

> Relating--learning in the context of one's life experiences or preexisting knowledge;
>
> Experiencing--learning by doing, or through exploration, discovery, and invention;
>
> Applying--learning by putting the concepts to use;
>
> Cooperating--learning in the content of sharing, responding, and communication with others;
>
> Transferring--using knowledge in a new context or novel situation--one that has not been covered in class (Crawford, in Dyer et al., 2006, p.

DESIGN AND PLANNING

Introduction

Leaders in the field of technology education believe that focusing technology education curriculum with engineering content will provide a method of incorporating cross-disciplinary standards-based instruction while meeting the goal of technological literacy (Hailey, Erekson, Becker, & Thomas, 2005). An engineering focus will require updating and enhancing much of the technology laboratory, equipment, tools, and materials traditionally used by technology education teachers. New teaching procedures are beginning to find an audience, and existing curriculum is being modified by the inclusion of engineering design into the curriculum. Research and experimentation have brought to light needed changes in the technology education laboratory. The following information provides research based material for updating technology education facilities.

Instructional and Support Spaces

Research suggests an overall square foot range of 3950 to 5450 for an engineering focused technology education facility that incorporates a prototyping, materials processing laboratory of 1000 to 1300 square feet (rated first). A range of 4950 to 6450 square feet is suggested for an engineering focused technology education facility that incorporates a prototyping, materials processing laboratory of 2000 to 2300 square feet (rated second). Professionals from the field of technology education rated 2 prototyping, material processing laboratories as significant. The ratings were: 1) 1000 to 1300 square feet 2) 2000 to 2300 square feet. Using these findings as a guide, the sample facility layouts were developed using the top rated 1000 to 1300 square feet prototyping, material processing laboratory.

Instructional Spaces

- 1000 to 1500 square foot combination computer, lecture, and presentation area
- 1200 to 1800 square foot flexible workspace for project staging, materials testing, creative problem solving, and team work space
- 1000 to 1300 square foot prototyping, materials processing laboratory (rated first) or 2000 to 2300 square foot prototyping, materials processing laboratory (rated second)
- 250 square foot CNC, CIM, and Rapid Prototyping area
- 200 square foot research and resource area

Support Spaces

- 200 to 250 square foot general storage and supply room
- 100 to 150 square foot equipment and tool storage room

Instructional and Support Space Furnishings

Professionals from the field of technology education have identified furnishings for each instructional and support space necessary for the inclusion of engineering design as a curriculum focus.

Combination Computer, Lecture, and Presentation Area

- Bookshelf storage case
- Bulletin Board
- Combinations CAD/Drafting student workstations
- Computer style chairs
- Rolling adjustable chairs
- Display cabinet with shelves
- File cabinet
- Instructor work station/desk
- Lockable storage cabinet
- Marker board
- Multimedia cabinet
- Printer table
- Projection screen

Flexible Workspace for Project Staging, Materials Testing, Creative Problem Solving, and Team Work Space

- Activity storage cabinet with tote trays
- Adjustable stools
- Lockable storage supply cabinets
- Mobile material and activity cart
- Printer table
- Prototype and testing stations
- Standard height student worktables
- Storage cabinet
- Teacher command station

Prototyping, Materials Processing Laboratory

- Activity storage cabinets with tot trays
- Demonstration table
- Large sink
- Lockable storage/supply cabinets
- Mobile materials and activity cart
- Standing height shop style workbenches

- Stools
- Storage lockers for student work
- Tool storage cabinet
- Wall mounted tool cabinets

General Storage and Supply Room
- Braced metal storage shelving or built in storage shelving
- Large plastic see through bins
- Lockable storage cabinet

Equipment and Tool Storage Room
- Lockable storage cabinet

CNC, CIM, and Rapid Prototyping area
- Adjustable stools
- Standard height student worktables

Research and Resource Area
- Bookshelf storage case
- Bulletin Board
- Computer style chairs
- Display cabinet with shelves
- File cabinet
- Work station/desk

Safety

Professionals from the field of technology education have identified facility and personal safety materials necessary for safe work environments for students and teachers who work within the engineering focused technology education facility.

Facility Safety
- Clear sight line within the space for student supervision
- Direct exhaust vents for each machine
- Emergency shut off switch
- Evacuation plans
- Eye wash station
- Fire extinguishers
- Fire resistant trash can
- Flammable storage cabinet
- General safety rules posted
- Safety glass sterilizing storage cabinet
- Hazardous chemical storage cabinet
- High impact safety glass in divided areas for teacher observation
- Large Sink & Soap Dispenser
- Machine specific safety rules posted at each machine
- Mounted first aid kit
- Paper towel rack
- Quick communication to main office
- Regulated air connection
- Safety signs
- Shield and guards on machines
- Sink with soap dispenser
- VTC in production and storage areas to minimize trip hazards
- Water Fountain
- Well marked safety zone areas

Personal Safety
- Dust masks
- Ear protection
- Eye protection
- Face shields

Tools and Equipment

Professionals from the field of technology education have identified tools, equipment, engineering trainers, and measuring and test equipment, as well as some basic supplies necessary for delivering engineering concepts within the engineering focused technology education facility

Hand Tools

- Adjustable Wrenches
- Ball Peen Hammer
- Bar Clamps
- Bench Brushes
- Bolt Cutters
- Center Punch
- Claw Hammer
- Coping Saw
- Crescent Wrench Set
- Desoldering Iron
- Divider
- Electronics Vise
- English Allen Wrenches
- English Wrenches
- Flat Head Screwdrivers
- Hack Saw
- Hand Drill
- Hex Wrenches
- Hot Glue Gun
- Level
- Magnets
- Metal Files
- Metal Punch
- Metric Allen Wrenches
- Metric Wrenches
- Nail Set
- Phillips Screwdrivers
- Plastic Mallet
- Pliers
- Pop Rivet Gun
- Rubber Mallet
- Sanding Blocks
- Scissors
- Socket Set
- Soldering Equipment
- Spring Clamps
- Staple Gun
- Straight Edges
- Tin snips
- Triangles
- Try Square
- T-Squares
- Tweezers
- Twist Drills
- Utility Knives
- Wire Snips
- Wire Strippers
- Wood Chisels
- Wood Files
- Workbench Vises
- X-acto Knives

Hand Held Power Tools

- Belt sander
- Corded Hand Drill
- Cordless Hand Drill
- Dremel Tool
- Grinder
- Hot Air Gun
- Hot Wire Cutter
- Jig Saw
- Router with bits
- Skill Saw
- Solder Pens
- Solder Gun
- Strip Heater

Material Processing

- 3D Printer
- Air Compressor
- Band Saw
- CNC Lathe
- CNC Mill
- CNC Router
- Combo Belt/Disc Sander
- Drill Press
- Grinder/Wire Wheel Combo
- Scroll Saw
- Table Saw

Engineering Trainers/Kits

- Automated Manufacturing Equipment – as specified within the material process equipment
- Variety of Electronics, basic electricity training kits (Gibson Tech, Tronix, etc)
- Variety of Robotics Trainers (VEX, LEGO Mindstorm, etc)

Measuring and Test Devices

- Adjustable Triangles
- Architects Scale
- Dial Calipers
- Engineering Scale
- Fast Read Thermometers
- Framing Square
- Graduated Metal T-Square
- Laser Level
- Laser Tape Measure
- Measuring Tape
- Metal Rulers
- Meter Stick
- Metric Ruler
- Micrometers
- Multi-Meters
- Oscilloscope
- Power Supplies
- Pressure Sensors
- Protractors
- Spring Scales
- Stopwatches
- Strain/Stress Gage
- Temperature Sensors
- Transit and Fulcrum
- Wind Tunnel

General Supply Items

- 3 hole punch
- Clear tape
- Colored markers
- Colored pencils
- Computer paper
- Construction paper
- Dry erase markers
- Engineering design notebooks
- Glue
- Masking tape
- Paper cutter
- Stapler
- Waste paper baskets
- Recycle bin

Computer Hardware, Software, and Audio Visual Equipment

Professionals from the field of technology education have identified computer software, computer hardware and audio visual equipment necessary for the engineering focused technology education facility.

Computer Software
- 2D CAD
- 3D Modeling/Design and Analytical
- Animation
- Architectural
- Civil Design
- Classroom management and supervision
- Clip art
- Data base
- Desktop Publishing
- Electronics training and simulation
- Engineering Training
- Internet Brower
- Mechanical workbench
- Multimedia and presentation graphics
- Multimedia generation and podcast
- Software for programming robots – PLC
- Spread Sheet
- Web-Design
- WestPoint Bridge Builder
- Word Processing

Computer Hardware
Student Use
- One computer per student – computer number should match the maximum class size, for example maximum class size of 28 students per sections there should be 28 student computers.
- One dedicated computer for each CNC machine that has been incorporated in the facility i. e. CNC - Robot, Mill, Lathe, Laser Engraver etc.

Computer Hardware
Teacher Use
- Instructor Computer - Suggested that teacher computer be high powered demonstration computer
- Laptop

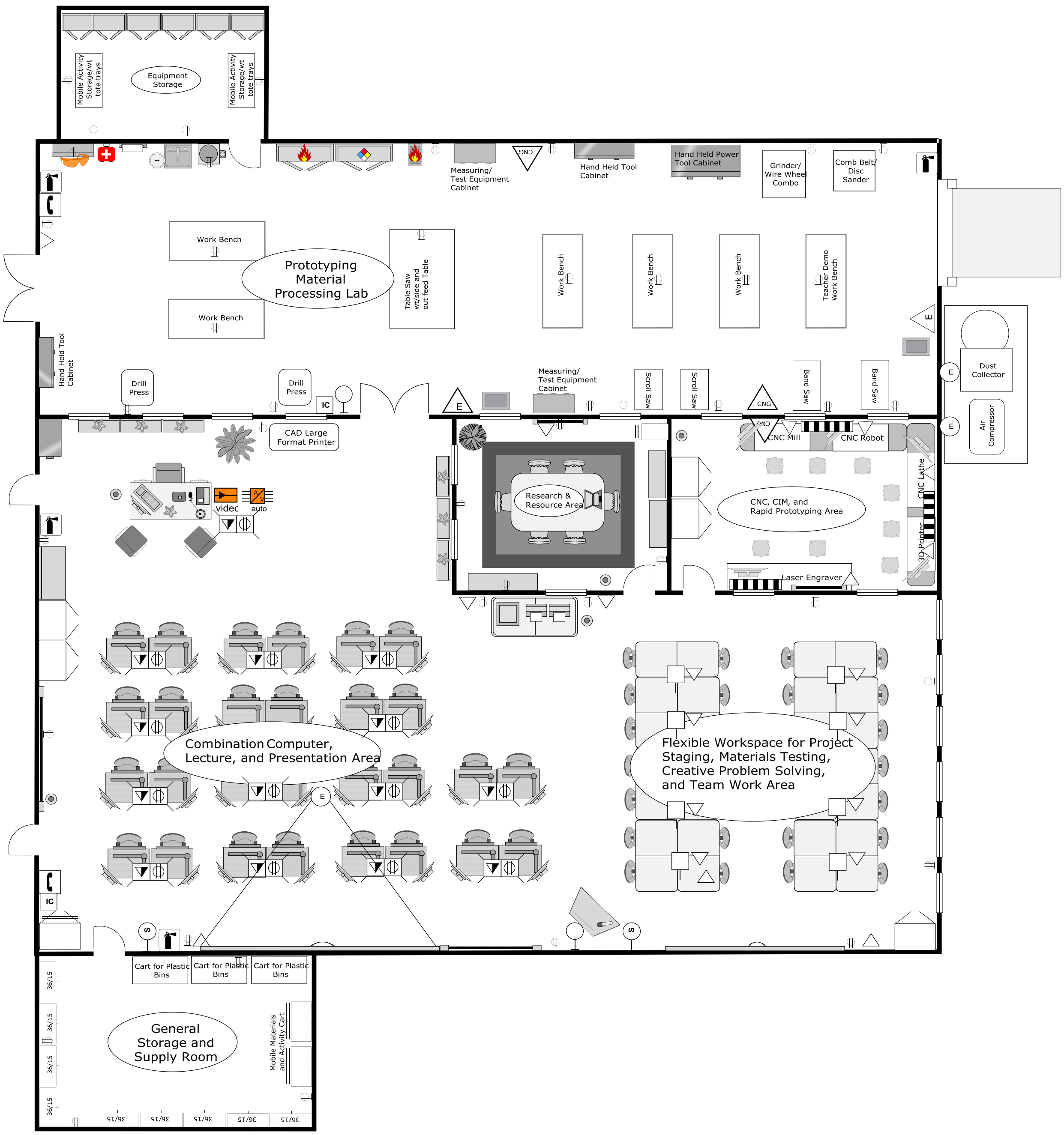
Printers/Peripherals
- Black and White Laser Printer
- Color Laser Printer
- Large Format CAD Printer/Plotter
- Scanner

General Peripherals
- Classroom phone
- Dedicated phone line
- Networked lab with internet connection
- Web Camera
- Wireless Mouse
- Wireless Pointer

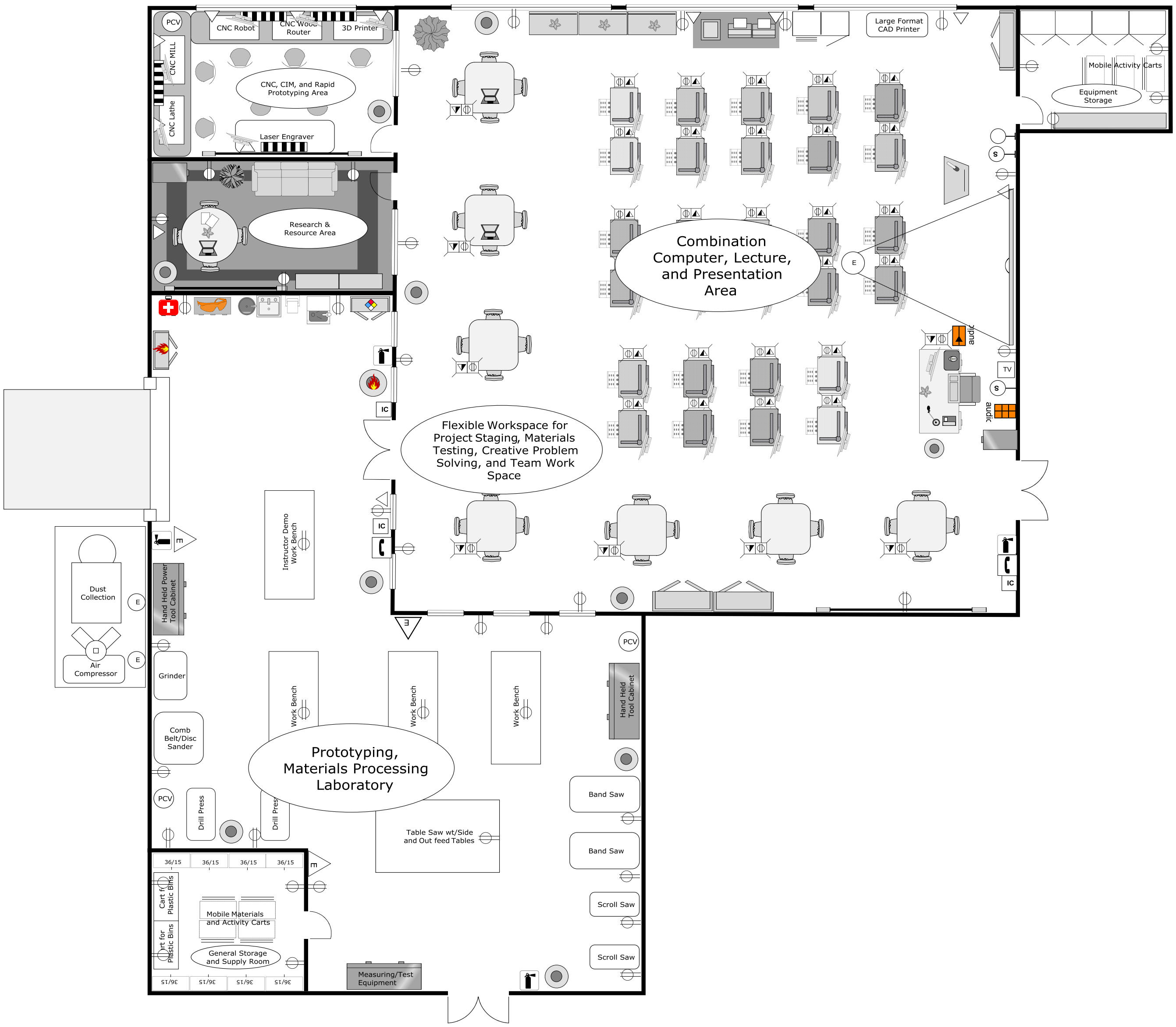
Audio Visual
- Computer projection system
- Digital camcorder
- Digital camera
- Interactive or Smart Board
- VCR/DVD combo player

SAMPLE LAB LAYOUTS

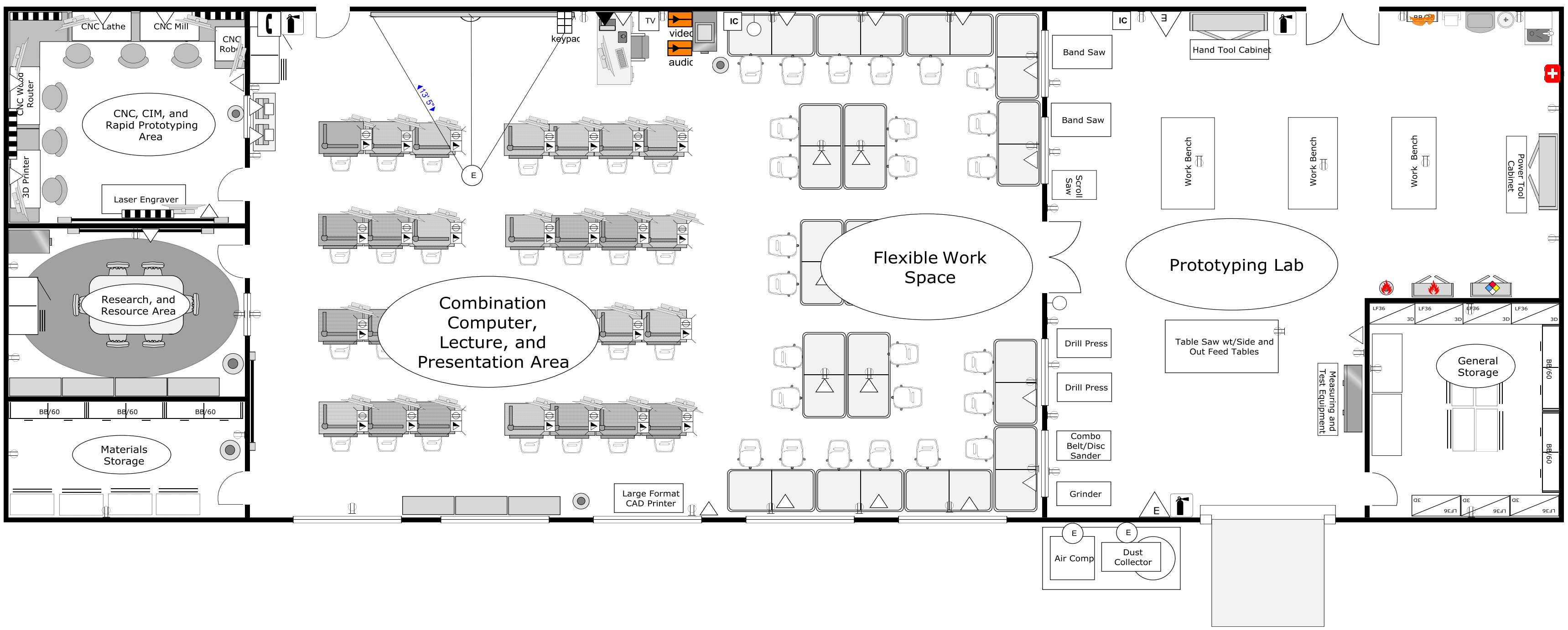
Laboratory Example – 4100 square feet



Laboratory Example – 4870 square feet



Laboratory Example – 3600 square feet



Implementation

As professionals from the field of technology education continue to struggle with how to best equip and configure engineering focused technology education facilities, several conclusions can be drawn from this research. As states start to move toward an engineering focused curriculum, professionals in the field of technology education should make use of research-based content as it relates to planning for today's engineering focused technology education facility. The development of facilities that emphasizes engineering design should be prefaced by present and future anticipated enrollments, local and world technological trends, program philosophy and goals, the instructional delivery system, and the availability of monetary resources. Currently there is no overarching framework for the understanding and implementation of engineering focused technology education facilities with regards to secondary education.

These support materials were carefully constructed in such a way as to provide tools and equipment for modern day engineering design focused technology education facilities. Given the educational philosophy and the constraint of 28 students, this document also identify educational and auxiliary room specifications (size and furnishings), safety considerations, measuring and testing devices, computer hardware and software, audiovisual equipment, and engineering focused kits and trainers in a meaningful and quantifiable method.

There are numerous groups of people that could benefit from these materials. First and foremost among them is the technology educations teacher. No one in the technology education program is better qualified to synthesize this study to assist in the process of laboratory planning than the teacher. The teacher has the unique training in drawing and design using CAD systems, and the relationships between various tools and equipment used during instructional activities. The technology education teacher has an overall understanding of laboratory requirements and can express them verbally, and graphically. In general, a well trained and experienced technology education teacher can be extremely helpful in advising on various matters that should be given attention with regards to facility construction and renovation.

Undergraduate students in teacher preparation programs majoring in technology education are an additional group who would benefit from this type of research. Often times, teacher preparation programs fail to provide instruction concerned with facility planning and construction. Historically, young teachers often find themselves involved in assisting in plans for a new facility or altering a laboratory already in existence (Nair, 1959). There is no doubt that incorporating an engineering focused curriculum will continue to provide the opportunity for new and existing teacher to redesign and configure instructional facilities.

There has been massive turnover in career and technical education administration at all levels, i.e. local, county, and state in recent years (Georgia Department of Education, 2008). This document was designed to give existing and new leaders in career and technical education, who may not have the expertise in the area of technology education, the necessary material for assisting with the design of new or existing technology education facility focused on engineering design.

Architects have an overwhelming job when planning and designing new schools or additions within existing schools. Many educational laboratories require special physical conditions to insure optimum teaching and learning. Band, chorus, art and most career and technical education i.e. business and computer science, family consumer science, as well as

Technology education courses require specific facilities - many of which are mandated through the state departments of education. This document was designed to aid and assist architects with the planning of new or renovated engineering focused technology education facilities.

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