AC 2007-642: ENHANCING APPLIED ENGINEERING EXPERIENCE: IN FRESHMAN MECHANICAL ENGINEERING TECHNOLOGY COURSE

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Enhancing Applied Engineering Experience: In Freshman Mechanical Engineering Technology Course

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Abstract

In recent years engineering and technology programs are challenged to prepare graduates to meet the globalization of the engineering profession and the real world demands of the global workforce. For the past several years, mechanical engineering and technology programs embarked on reforming the curricula by introducing new courses at the freshman level to enhance student motivation and improve retention. This paper talks about how the existing courses at freshman level in the area of mechanical detailing, technical graphics and manufacturing methods were used innovatively to provide the real world experience of product design, manufacturing and operation. It also shows how the program addresses part of the CDIO (Conceive, Design, Implement, Operate) framework. Students taking the mechanical detailing course are involved in reverse engineering project. Students work in teams in redesigning the product, developing technical drawings, exchanging drawings with a different group to manufacture their product, and test and operate the product. This approach demonstrates the real world workplace environment of product design and manufacturing in which technical knowledge and other skills are learned and practiced. The freshman course project is an early exposure to students to demonstrate the relevance of mechanical engineering technology. It helps the students see graduates as practitioners of the profession, implementers of technology, job-ready and focused on applied engineering.

Introduction

The trends in globalization, rapidly emerging technologies, and societal changes are challenging the engineering and technology profession to prepare professionals for 21st century. These emerging trends in engineering technology education facilitated by the Technology Accreditation Criteria 2000(TC2K) developed by the Accreditation Board of Engineering and Technology (ABET) is promoting the preparation of engineering technology graduates as practitioners of the profession, implementers of technology, job-ready and focused on applied engineering. One of the major challenges is early introduction to the design and manufacturing skills. During recent years many mechanical engineering and mechanical engineering technology programs revised, modified, or even initiated new design experience courses into the classroom. These courses were introduced to address design, manufacturing, communication and teamwork skills. Some programs developed new courses with integrated disciplinary knowledge and project based courses with simulation. Instead of developing new courses, the mechanical engineering technology program faculty used the existing courses to demonstrate the connectivity of courses to the profession and skill development. This paper describes the idea of using a "Footstone" type project in the freshman year. This project introduced and enhanced applied engineering experience at early stages in the program to provide experiential learning, real world workplace simulation (product or system building experience), inter-team and intra-team communication, and exchange product drawings with other teams, design, build and test a product.

Background

The need for reform in engineering and engineering technology education has been widely discussed at conferences, forums, and in journals for several years. A number of freshman-level courses have been created to integrate technical and non-technical skills through design projects. Scope of these projects varies significantly. Some projects involve studying the product functionality, design and manufacture, while other projects involve new part designs. These courses varied in content and implementation. Some courses had several multi-week projects, while others had a single project over the entire semester. The concept of helping students understand the functionality of a product, its individual components, and operation can be highly motivating and challenging. Several academic programs have developed a sequence of courses to integrate design and real world experience throughout the length of the program. One should not underestimate the benefits of each approach. Each approach has a positive impact in bringing the real world experiences to students in academic programs. So, what is done differently at Kansas State University at Salina?

Footstone Project for Connectivity

The importance of introducing a 'Footstone' project at an early stage of the students' engineering technology program has been recognized by the mechanical engineering technology faculty for over two decades. The essential elements of these projects were to provide an active learning environment at the very outset of the freshman year program. Team work, both at the student, as well as at the faculty level was integrated. This case study describes how one of these projects has been used to continually develop and include highlighting the connection between theory and practice, between courses currently being taken by the students and the work experiences or the internships they may be concurrently going through (horizontal connectivity), the courses and work experiences of the yester years as well as to be taken by them in the future years (vertical connectivity), and the importance of brains-on hands-on approach to engineering technology education.

It was the high-pitched high-tech era of early eighties that prompted the faculty to take a totally fresh look at the program. Increasingly expanding the knowledge base in all fields and the expensive high-tech related applications on the one hand and the shrinking financial resources on the other demanded innovative and creative ways to come up with feasible solutions if the teaching and learning process was to continue to be meaningful. The so called 'Optimized Computer-aided Teaching And Learning' (O.C.T.A.L)[1] concept was developed. This needed pulling down of several isolating and turf protecting barriers. Cooperation and coordination on the part of all the faculty was the key to the success. Each contributed to, as well as learned from the rest. In other words the faculty 'group' or 'team-work' concept was born. The success story prompted to extend the 'team' concept to students at as many levels and in as many courses as was feasible. The next development was the 'integrated group' approach to the teaching and learning process. This would possibly enable a greater topic or knowledge base to be covered in the classes along with a feel for creativity, curiosity, and camaraderie without confrontation. It was also deemed necessary that the essential features of teamwork -- cooperation and coordination -- must be learned early in order to be successful team players on future real world engineering teams. This finally led to the so called 'Footstone Project' concept[2]. The idea was distinct from the 'capstone' design projects in that it was simply a tool to be used at the very outset of a program of study to help set a stage for the teaching and learning process as it pertains to the courses of studies and as it bears on the practice of engineering and technology. It was a 'pilot' for the implementation of the 'integrated group' approach. It was not to be the culmination or test of the learning in a program as a whole nor was it to be a stand alone course objective as is generally expected in a capstone project. It was to be a part of one or more courses in order to avoid even a hint of erecting walls in learning.

Faculty in this program has been giving various projects from tiny through to mid-size levels for a number of years to their students in several courses. The design and manufacture of a small air motor shown in figure 1 attracted the attention of freshmen. The tiny motor seems to have a tremendous motivational power, and it was decided to exploit this aspect to the maximum.

Another tough challenge faced by engineering and technology schools, pointed out by Bickart[3] is the education and training of the needed manpower commensurate with the national needs and requirements. His suggestions point more towards ethnic pluralism to improve recruitment as well as retention to sustain the flow of students through the pipeline by improving their socialization, study skills and enlarging their knowledge base. "Their involvement in engineering experiences, from student professional group activities to undergraduate research and design projects, must begin early." The authors' experiences have identified equally good applicability of these concepts and ideas of collaborative learning to achieve similar results in groups or teams with a large degree of abilities and background variations even in the ethnically uniform group. This problem can become certainly acute in colleges and programs with open admissions policies and which generally attract levels of academic achievements of entrants less or much less than the ones attracted towards competitive engineering programs generally. Many engineering technology programs fall into this category. Such programs by necessity will have to be more innovative and creative to include these same traits in their students. We believe the 'integrated-group' approach is a positive step towards this objective.

A touch of shock and awe in any presentation is always helpful in attracting the students attention, be it a lab or lecture. The greater the number of human senses getting involved during the process, the greater the chance of retention of the underlying concepts and appreciation for the learning objectives. Visualization techniques have always been an essential part of the teaching and learning environment in engineering and technology related fields of education. Sketches, drawings, films and multimedia play an important role. Models – paper, cardboard, plastic, wood – add to the scope of understanding. Actual full size parts and assemblies along with their operational and testing facilities further enhance the hands on approach to the understanding and verification of a wide variety of phenomena which generally come at a considerable cost. Engineering technology students especially have a strong need for approaches that combine hands-on and easy-to-visualize techniques that have a lasting impact on the student understanding and conceptualization of theory and related mathematical analysis. Constraints of perennial financial stress at the institutions of higher education have forced the faculty to innovate techniques at low-cost or no-cost basis.

At KSU-S, the MET program offers both the associate and bachelor degrees. These programs are based on 2 + 2 concept. Students enroll in associate programs and after completion, some continue in the bachelors program. The MET program has a heavy emphasis on hands-on experience integrated into several courses. Our current MET program provides a mix of design and manufacturing related courses. The footstone project is introduced in MET 117 Mechanical Detailing and MET 125 Computer Numerical Control (CNC) Machine Processes. The project is a common assignment in both courses. These are offered as freshman second semester courses in the associates program. During the first semester students acquire basic skills in technical graphics, computer-aided-design (CAD) and manufacturing methods. Mechanical detailing class introduces students to the preparation of shop drawings for manufacturing, fabrication, and/or assembly, specification of size, shape, material and manufacture in conjunction with CAD. The CNC Machine Processes course emphasizes basic concepts of CNC, manual part programming with G and M codes on lathes and milling machines.

Framework for Student Learning Outcomes

The student learning outcomes (SLO): passion for the profession, inter-team, intra-team, leadership, communication skills, and product and system design skills, integrating disciplinary knowledge are assessed at the successful completion of the "footstone" project. It is necessary to explain the need and connectivity of these student learning outcomes within the context of TC2K and CDIO (Conceive, Design, Implement, and Operate) framework. The CDIO initiate has been promoted as an innovative educational framework for producing the next generation of engineers. The CDIO™ Initiative was developed with input from academics, industry, engineers and students. It is universally adaptable for all engineering schools. **CDIO™ Initiative** collaborators throughout the world have adopted CDIO™ as the framework of their curricular planning and outcome–based assessment. It is evident that the purpose of both the TC2K and CDIO initiative is to prepare the next generation engineering and technology professionals. Table1 demonstrates the mapping of CDIO Syllabus to ABET EC2000 and TC2K SLOs.

Table 1. Mapping of CDIO Syllabus to ABET EC2000 and TC2K SLOs

	ABET EC 2000 and TC2K OUTCOMES										
CDIO Syllabus Condensed Form	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
1.1. KNOWLEDGE OF UNDERLYING SCIENCES	■										
		●									
1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	■										
		●									
1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE	□										■
	●										
2.1 ENGINEERING REASONING AND PROBLEM SOLVING					■						□
						●					
2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY		■									
			●								
2.3 SYSTEM THINKING			□								
			○								
2.4 PERSONAL SKILLS AND ATTITUDES									■		
								●			○
2.5 PROFESSIONAL SKILLS AND ATTITUDES						■					□
									●	●	○
3.1 TEAMWORK				■							
					●						
3.2 COMMUNICATION							■				
							●				
3.3 COMMUNICATION IN FOREIGN LANGUAGES											
4.1 EXTERNAL AND SOCIETAL CONTEXT								■		■	
										●	
4.2 ENTERPRISE AND BUSINESS CONTEXT											
4.3 CONCEIVING AND ENGINEERING SYSTEMS			■								
				●							○
4.4 DESIGNING			■								
				●							
4.5 IMPLEMENTING			■								
				●							
4.6 OPERATING			■								
				●							

■	EC Strong Correlation
□	EC Good Correlation
●	TC2K Strong Correlation
○	TC2K Good Correlation

Source: Edward F. Crawley, MIT

Course connectivity addressing the CDIO Syllabus framework is shown in Figure 1.The following diagrams shows the students the connectivity of courses in CDIO framework to understand how to apply the acquired knowledge in previous courses, assimilate to new knowledge and integrates disciplinary knowledge.

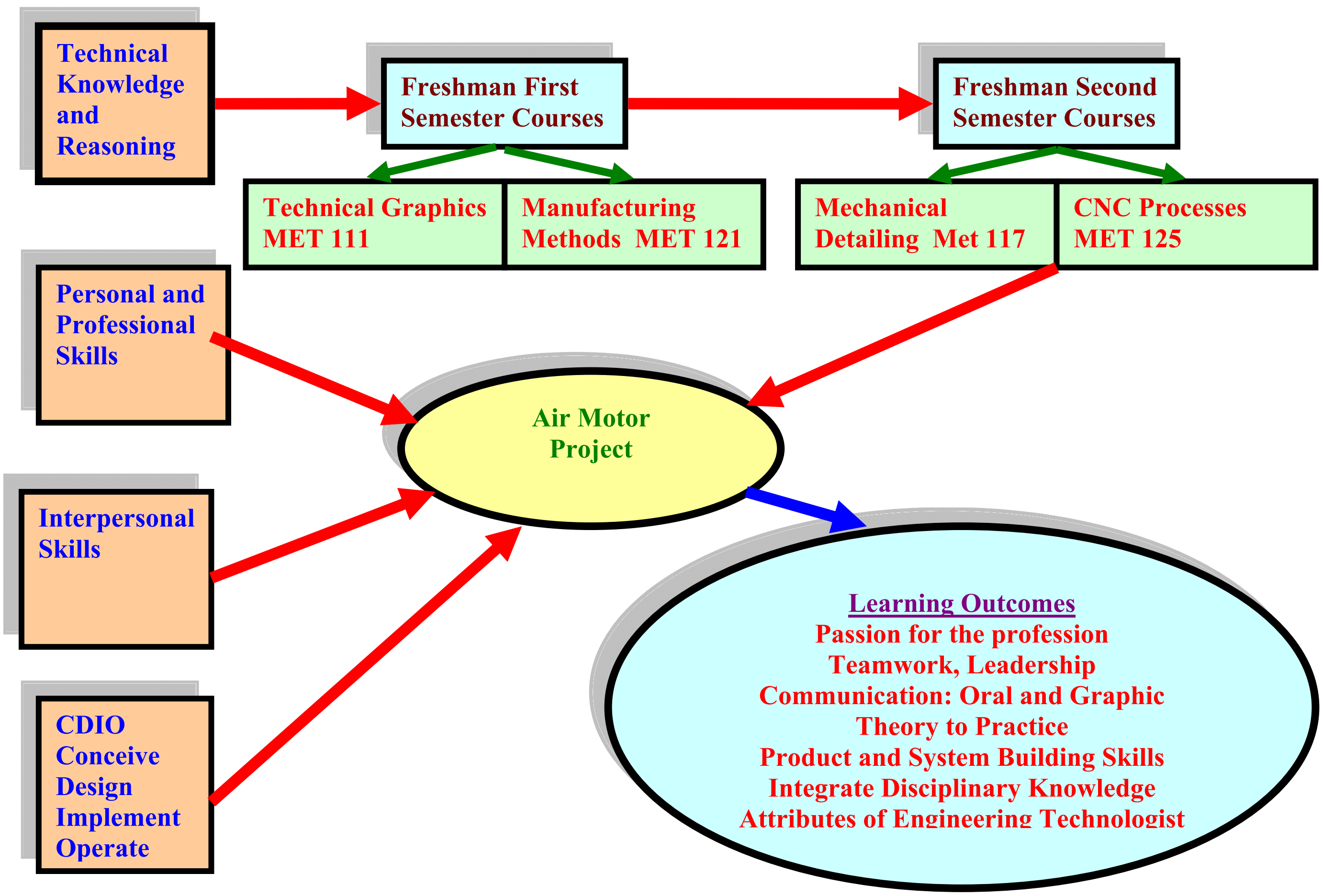


Figure 1 Course Connectivity to CDIO Syllabus Framework

Specific knowledge acquired in the courses relevant to successfully apply in the 'Footstone" project is explained in Figure 2.

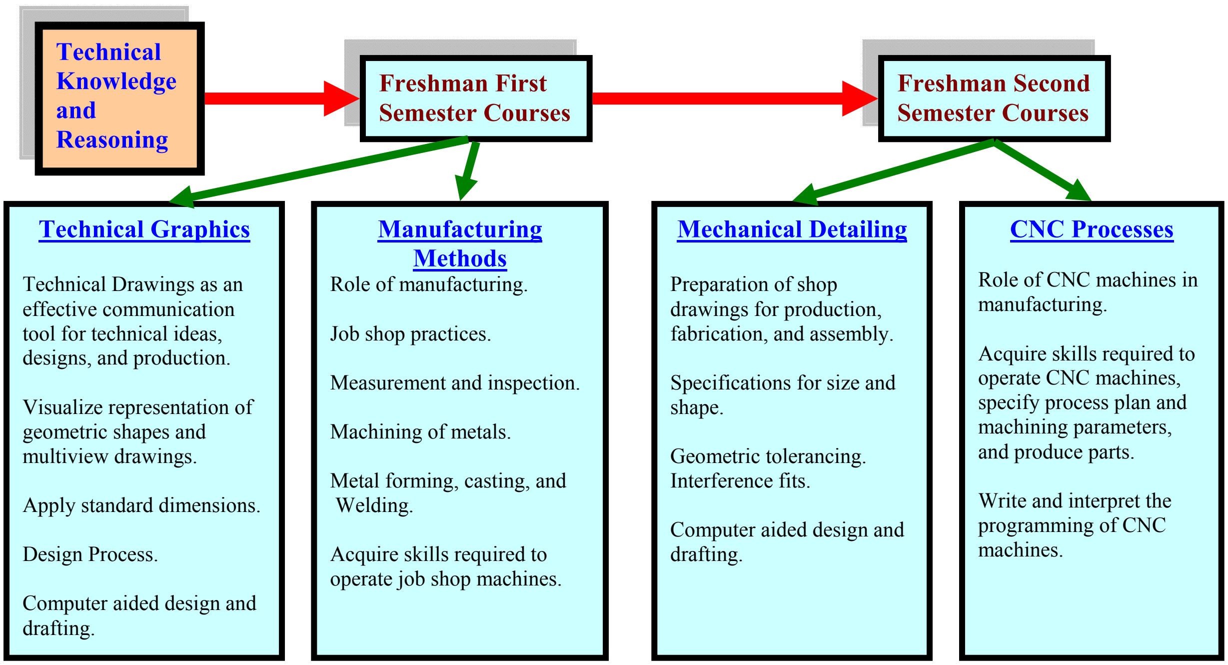


Figure 2 Knowledge Acquired in Courses

Integration of disciplinary knowledge is explained in Figure 3.

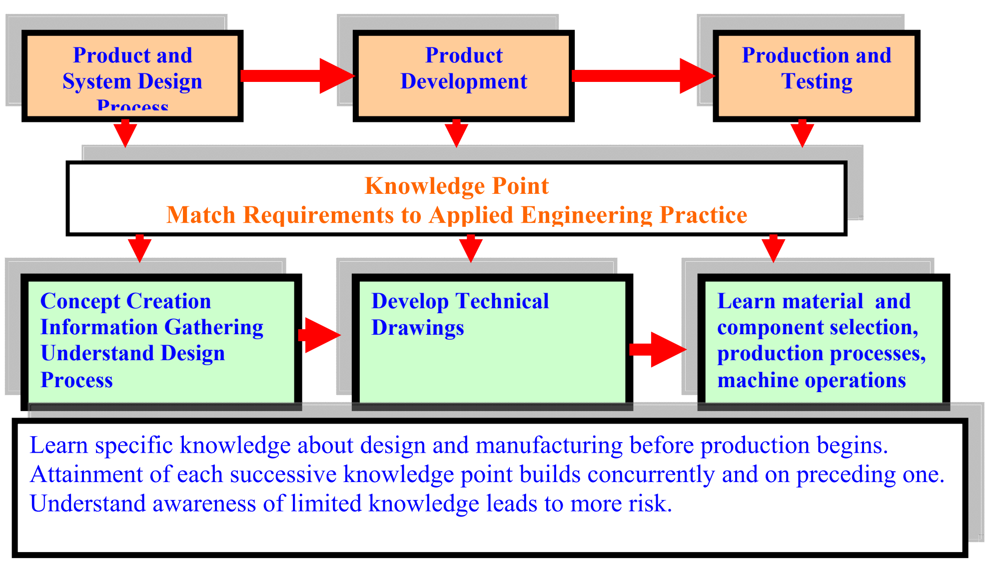


Figure 3 Integrated Disciplinary Knowledge

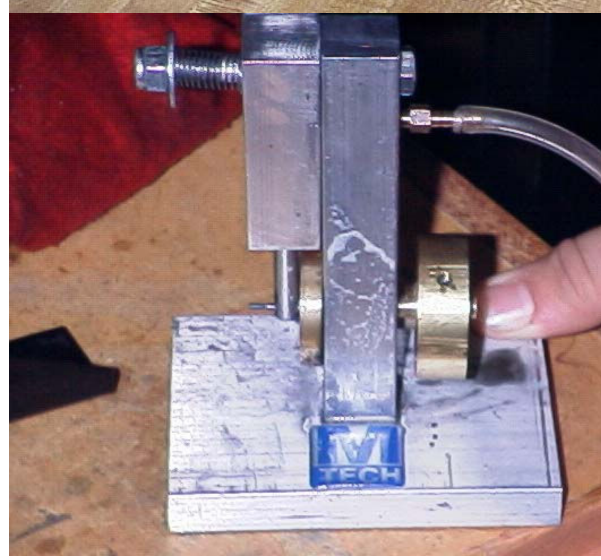
Air Motor Project

This project involves measurements, review and changing of sizes, materials, and decision making on process selection. The work also involves preparing detail drawings, assembly drawings, as well as graphing work - all to be done using computer techniques. Simulation using animation with a CAD software to observe the proper functioning of the ports.

The following specifications must be kept in mind in the design and manufacturing of the AIR MOTOR:

- Envelope dimensions shall not exceed 3x4x5 in inches.
- Either horizontal or vertical piston movement.
- Single piston - no impeller - no rotary valves.
- Maximum air pressure allowed is 60 psi.
- Inlet port to be threaded to accept tubing compatible with available lab sizes.
- Single acting.
- Drive shaft to be supported by a bushing.
- Bushing must be capable of delivering oil to drive shaft.

Do reverse engineering of Air Motor.
Come up with your own and improved design.
Exchange your product drawings with another group. (So the other group can manufacture the product)
Do literature searches to identify patent information on air motors.



Student Feedback

Several encouraging remarks have been received from both the current as well as past students over the last several years. Some of these excerpts are reproduced here unedited to give some insight into the usefulness of this type of a learning tool: "....Probably the thing that I learned the most was how important communication is in getting a product finished. The project that I learned this was designing the air motor. I learned that if I didn't dimension something, it made a big problem for the builder. I also had to make my drawings clear for the builder to understand. The builder also ran into problems with some of my parts, so I had to redesign them to fit the equipment in the shop. All in all, I found that a person can have a good idea, but if he can't communicate with the builder and produce good drawings, it is useless..."; "...The air-motor project was definitely the most time consuming assignment of the semester, but in return it was the most rewarding. This assignment required the use of AutoCAD and MathCAD, lots of time and cooperation with the builder. My original design was shot down by the professor because it had rotary valve, so it was back to the drawing board. After developing a new concept I began the drawings for my new plans. The hardest part of the design was figuring the location of my inlet and exhaust ports, because if these are not correct then you are wasting your time. I figured the location of the air holes using AutoCAD which took some time, but after I was finished there was no doubt that my motor would run. Simulating the motion of my motor using CAD eliminated any doubts about whether or not it would run this was the most rewarding assignment of the semester, there was no better feeling than seeing your motor run knowing how much time and effort you had invested into this project.. .This assignment showed how much work goes into designing simple machines and the amount of details that are required... .Communication and cooperation was also one of the key ingredients of this assignment. If the project did not have good communication it would probably never have worked..."; "....This assignment was probably the most fun but most challenging. We had to design our own motor from different experiences we learned throughout our college career. The best memory of the course was when my motor was completed, hooked up to air pressure, and the motor turned over and ran so hard that it shook the pin right off the flywheel!...". "...Going in, I had no idea how the motors worked or how I was going to make mine. During the whole semester, my builder and I kept in contact. Our good communication allowed him to get the project done ahead of everyone else in our lab section. He never had to wait for me to get him the drawings. Not everything went as planned, but this just added all the more to the learning experience. Communication and working with others is a big part of industry and was also a big part of this project.". "It makes learning more interesting and appealing when the class can take an active part in the situations being discussed. Communication is the key to a smooth and trouble free operation..."; "....the big catch of it all was that we did not get to build our own design. And that taught us all a good lesson....how to make our plans so other people could read them. We started out by just talking about the different options. This led to drawings and discussions in front of the class. In all from doing the air motor I do not feel so ignorant of knowing how to use different software, manufacturing processes and the basics in design."; "...the most important thing I learned was from the air motor assignment....it is important to give tolerances."; "While living on the farm I often had to replace and repair bearings and shafts on tractors and other pieces of farm machinery, but I never realized that the tolerances between the parts was so exact and there was such a different range of possible classes of fits and sizing."; "This was a very interesting class for me because I knew a little about most of the stuff we covered, but I learned something about all of it. The biggest thing I learned from the class was how hard it was to design several parts that work together without building anything."; "I was very surprised at the calculations that need to be made to find compressive stresses, as well as shear stresses in keys and keyways. I had thought keys and keyways could be cut just about any size for different shafts and hubs."; "I learned that when designing a project one can't just start pulling numbers out of their head. They need to know how they interact in the whole project for a good design. Also, one should design a part so that it can if possible be machined easily with the fewest steps possible. This I feel I learned here."

Summary and Conclusions

Freshman mechanical engineering technology students participating in 'Footstone" project enhanced applied engineering experience. Further the early introduction of project demonstrated the relevance of mechanical engineering technology graduates as practitioners of the profession, implementers of technology, job-ready and focused on applied engineering. Through the project experience students understood the connectivity of courses, related knowledge, specific application of knowledge within the context of TC2K and CDIO framework of student learning outcomes in preparing next generation engineering technology professionals.

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Masud A. Hassan is currently a professor of mechanical engineering technology with a varied and extensive experience in engineering and engineering technology education spanning over forty years in industrial and university settings. His education and work experience covers several counties around the world. He possesses Bachelors, Masters, and a Doctorate degree in mechanical engineering and has developed and taught a wide spectrum of courses related to mechanical engineering and engineering technology.

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Dr. De Leon is Professor and Head of Engineering Technology at K-State at Salina. He worked 10 years in industry prior to joining academia where he served 11 years as a faculty member teaching in areas of computer aided design, quality control, industrial ecology and industrial safety. He has published several manuscripts on subject matter related to these curricula. His scholarly pursuits include securing extramural funding for assisting traditionally underrepresented students in engineering complete their education