AC 2012-5238: INTRODUCTION TO MECHANICAL ENGINEERING: A COURSE IN PROGRESS

Dr. Lisa Abrams, Ohio State University

Lisa Abrams, P.E., Ph.D., is an Assistant Professor of Practice in the Engineering Education Innovation Center and the Department of Mechanical Engineering at the Ohio State University. Prior to this position, she worked as the Director of Women in Engineering at Ohio State and as Assistant Dean in the School of Engineering and Applied Science at Miami University. She also has seven years of industry experience. She received her B.S. and M.S. in mechanical engineering at Ohio State and Ph.D. in industrial engineering at Ohio State.

Prof. James William Altschuld, Ohio State University

Emeritus

Dr. Blaine W. Lilly, Ohio State University
Prof. Daniel A. Mendelsohn, Ohio State University

Dan Mendelsohn is an Associate Professor of mechanical and aerospace engineering at the Ohio State University. He received his doctorate in theoretical and applied mechanics from Northwestern University in 1979. His current research interests include nonlinear wave propagation and vibrations in damaged materials and evaluation and assessment of curriculum related to problem solving and design. Mendelsohn is a member of ASME and ASEE.

Introduction to Mechanical Engineering: A Course in Progress

Abstract

Due to a Summer 2012 conversion from quarters to semesters, the Department of Mechanical and Aerospace Engineering at The Ohio State University has embarked on an effort to revamp and enhance its design sequence. This began in the Spring and Summer of 2010 with graduating student exit interviews, alumni focus groups, and faculty retreats culminating in a modification of the current design sequence at the university. This paper focuses on a new design course for second year students admitted to Mechanical Engineering. The objectives are two-fold: (i) to enhance student's foundational knowledge, skills, and associated intuition, and (ii) to introduce the students to open–ended design problems. The course is focused on the design and fabrication of functional artifacts. Students will work in teams to construct a compressed–air motor from a kit of parts, most of which will require machining to close tolerances before assembly. They will use an Arduino microcontroller to control inlet air pressure to the motor. Then each team will proceed to design and prototype a device that will be driven by the output shaft of the motor and which will perform a useful predetermined task.

The overriding challenge of this course is in the numbers of students who are required to take this course. The Department of Mechanical and Aerospace Engineering is the largest department in the College of Engineering with 1215 students majoring in Mechanical Engineering. It is estimated that approximately 200 students per semester will take this new design course.

Two pilots of the new design course will be completed before the semester implementation in Fall 2012. Assessment instruments of the pilots include assignment rubrics, focus groups, surveys, and questionnaires. This paper includes some of the preliminary data collection and results and issues encountered by the development team.

Introduction

The Ohio State University (OSU) is a Research 1 land grant institution. Mechanical Engineering at OSU has historically had a traditional curriculum with a hands-on design experience in the first year, theoretical and laboratory experiences in the second and third year, and a senior capstone in the fourth year.

The decision was made to convert from quarters to semesters which required an reorganization of the undergraduate and graduate curricula. The Department of Mechanical and Aerospace Engineering looked at the conversion as an opportunity to make significant changes that would strengthen and better position the graduates in an increasingly competitive and global engineering workforce. With this objective in mind, the Department corresponded with 300 alumni from the last 20 years, sought feedback from them on the curricula, and invited them to join a selected faculty group on campus in July of 2009 for a full-day discussion of curricular changes. 130 alumni responded to the invitation and electronic survey and 45 alumni joined over 15 faculty members for a vigorous full-day discussion on campus. Visits also were made to and from leading engineering programs around the United States to gain additional perspectives.

With this alumni and engineering educator input, numerous exit interviews, student surveys from the past 10 years, and considerable faculty discussion, a faculty committee was able to draft a proposal for the new curriculum.

In brief, the most significant changes include a reduction and reorganization of required courses in the core curriculum, the addition of a required statistics course, the addition of a sophomore level design course, and the overhaul of the approach and timing of the labs and hands-on experiences.

This paper focuses on the new sophomore level design course which has been piloted as an abbreviated ten-week quarter long version in Autumn 2011 and Winter 2012. The sophomore course fills, in part, the major gap in design education that exists between the fundamentals of engineering course sequence (and its honors equivalent, both of which serve as a prerequisite to the major) and the senior-year capstone design course. And while the first year course sequences include a design-build project, there exists a wide variance in the machine skills and experience of entry-level Mechanical Engineering students. This new sophomore course attempts to level-set the practical knowledge of machining among students in addition to filling the gap between the first- and the last-year design experience. This course is also intended to be an introduction to the whole discipline of mechanical engineering. Students will be exposed to mechanical design, fluids and thermal sciences, dynamic systems and controls, and motivate them for later courses in these areas. Students will also be expected to gain proficiency in data acquisition systems, CAD/CAM software and other common computing programs, as well as to sharpen their oral presentation and written skills.

Developing a hands-on Mechanical Engineering sophomore level course is not necessarily revolutionary as there are many schools are starting to focus on retention in the sophomore year. Villanova University[1], Georgia Tech[2], and Kettering University[3] have recently documented new sophomore level design courses focusing on providing a broad introduction of mechanical engineering and the fabrication of a device. University of Houston[4], Purdue University[5], University of Southern Alabama[6], RPI[7], and Virginia Tech[8] also have sophomore level courses but focus more on the design and design process. Other schools such as Pennsylvania State University[9] and Rowan University[10] are focusing on multidisciplinary or multinational design teams. The University of Utah[11] has addressed the challenge of large class size and has recently modified their curriculum to utilize more hands-on and active learning concepts with 150 students per term. Mechanical Engineering at OSU shares this challenge with expected enrollment of sophomores up to 300 students per year.

The fourteen-week semester course will begin with a two week study of typical design and production steps – everything from exploring materials selection and manufacturing processes to analyzing systems and components. This study will include disassembling some common workshop items such as small electric drills or power screwdrivers and discerning how and why the manufacturer produced and then marketed the selected tool to the consumer. The following four weeks will be spent machining and assembling a small air motor. Students will investigate variations in the motor design and perform basic tests on the motors. They will then use an Arduino microcontroller to control inlet air pressure to the motor. The final four weeks will be more open–ended, allowing students to design and prototype a device that will be driven by the output shaft of the motor and will perform a useful predetermined task. The course is also meant to address additional employer concerns about teamwork, communication, and project management skills.

Overview of First 10 Week (Quarter) Pilot Course

It was determined that 24 students would be optimal for the first pilot course in terms of machine shop staffing and equipment. An evening information session was held in the Spring for students to learn about the pilot course. A short application was given to those students who were interested in enrolling. Of the 37 applications that were received, 26 students had course schedules that permitted adding the course to their Autumn quarter schedule. 21 students were male and 5 students were female. The Autumn course involved two 90 minutes lectures and one two hour lab per week. Students earned technical elective credit once successfully completing the course. The general outline of the course is shown in Table 1.

Week	Lecture	Lab
1	Introduction	Lab Safety
2	Thinking Functionally; Design Constraints	Product Teardowns
3	Technical Communication: Writing; Technical Communication: Sketching	Performance Tests
4	Technical Communication: Prototyping Managing Team Projects	Air Motor
5	Student Presentations Measurements, Tolerances, Fits	Air Motor
6	Basic Machining	Air Motor
7	Computer Aided Design Thermodynamic Cycles and Heat Engines	Air Motor
8	Machine Components	Air Motor
9	Technical Communication: Presenting Your Data; Technical Communication: Spoken Word	Air Motor
10	Technical Communication: Presentations Conducting Yourself Professionally	Air Motor
11	Student Presentations	Air Motor

Table 1. Outline of Ten Week Pilot Course

The objectives of the ten week pilot course were:

- Have an understanding of how the major interest areas in mechanical engineering relate to each other and to the kinds of problems that mechanical engineers are typically asked to solve;
- Have exposure to decomposing, analyzing, and modeling real systems at a basic level;

- Be able to communicate design ideas effectively by means of hand sketches, rough prototypes, dimensioned drawings, the written word, and oral presentations;
- Be proficient in the use of basic machine tools, data acquisition systems, mechanical and electrical measuring devices, Solidworks CAD and CAM software, Matlab, and Excel;
- Be proficient at working on design teams;
- Be proficient at keeping a design notebook and preparing a poster documenting work in class;
- Be able to design mechanical components and basic systems at a professionally acceptable level of competence, and possess a firm basis for continuing in the field.

The lectures were conducted by one of the two instructors of the course or a guest speaker. Most of the lectures included a homework assignment, quiz, or active learning activity during the class session.

The first five lectures included a persona and scenario assignment as part of a design exercise to evaluate and assess students' writing abilities as well as teach sketching and prototyping. The design task was to create a method of transporting five eggs without breaking any of them. The design included creating a persona, a plausible scenario involving that persona, and an actual prototype to hold five eggs. Students received feedback on their persona and scenario drafts before a final version was due.

Beginning in week four, and continuing throughout the remainder of the ten–week academic quarter, the students in teams of four focused on constructing a two–cylinder compressed air motor that was at the heart of the course. Students received in–class instruction of machining operations such as milling, turning, boring, reaming, and tapping, which they immediately put into practice in two–hour lab sessions in the machine shop. These lectures were followed by lectures on common fasteners and their uses, machine components, drawings, and determining adequate tolerances.

The lecture material was reinforced by its immediate application in the machine shop. The lectures were explicitly designed to connect very closely with each week's activities in the shop, with the result that in most cases the students received both theoretical and practical domain knowledge within one or two days of each other.

Overview of Course Assessment

Prior to and during the first pilot course, numerous meetings were held with the course instructors, several Mechanical Engineering faculty, the Department Chair, and an external assessment evaluator. The focus of the meetings was on the goals, content, instructional strategy, flow of topics, and possible approaches to evaluation. Many ideas on assessment were discussed: what could be done with the available budget, what key variables should be looked at, what were the goals of the course, what instrumentation could be used or modified for use across different parts of the design sequence, how should open-ended assignments be scored, how adequate and utilitarian are the scoring rubrics, and what comparisons could be made in an experimental or quasi-experimental manner across segments of the curriculum.

What resulted from the deliberations is summarized in Table 2. Six activities for evaluation were undertaken or are in progress at the time of writing. This paper focuses on the pre and post Power Point perception assignments, the Focus Group Interviews (FGI), and the end of course evaluation.

Evaluation Purpose	Strategy	Instrumentation	Current Status
Determine student perceptions of Mechanical Engineering	Pre/post assessment of perceptions to see if there was change Possibly generalize to other courses	Power point assignment at the start of the term and then asking for changes at the end	Approximately 600 statements from pre and post have been analyzed
Formatively monitor the course for improvement	Mid-term and end-of-term focus group interviews (FGI)	Identical focus group interview questions	Both FGIs have been completed, the first has been analyzed and the second is in progress
Group discussions of the 2900 instructional team to improve course as it progressed	Interactions of team at meetings or informally	No specific questions; just discussions	On-going
End-of-term course evaluation student survey	Administer the survey one time to obtain student views	Survey developed by instructors Detailed evaluator developed survey for possible use next time	Data collected in December Review of evaluator survey required
Determine the quality and utility of several scoring rubrics	Have independent scores use rubrics to see how they work and if results are reliable	Adopted existing rubrics from other courses or materials	In process
Administer an Attitudes toward Mechanical Engineering Survey	Administer scale early in program to see what the attitudes are but also if they are predictive of persistence	Draft items have been prepared along the lines of work done at the University of Pittsburgh[12]	Efforts in this area are just beginning

Table 2: Overview of the Evaluation Strategy as of December 2011

Methods of Assessment

The students were asked to develop a Power Point assignment assuming they were presenting to a group of 9th and 10th graders at their high schools' career day. They were to describe (not proselytize) Mechanical Engineering in regards to "What is Mechanical Engineering?", "What do Mechanical Engineers do?", "What are the Advantages of being a Mechanical Engineer?", and "What are the Disadvantages?" The assignment can be found in Appendix A. Aside from title slide, each question was to be answered on a Power Point slide and then returned to the evaluator and instructors. The post version of the assignment was for students to review their original assignment and make any changes that they wanted. They were not required to do so if they felt comfortable with what they had done previously. Twenty six students in the design course completed the pre-assignment and 24 completed the post assignment. 10 students made no changes; 14 students did make changes; and 2 students did not respond to the post assignment.

The pre and post Focus Group Interviews (Appendix B) were similar with the only difference being appropriate to whether the course was in progress or had been completed. After a warm up question, the discussion dealt with questions such as the organization of the course, working in teams, what they felt they had learned, and other parts of the experience. Four males and two females were in the first group and four males and one female were in the second. A summary of the final course evaluations can be found in Appendix C.

Results of Assessment

In analyzing the pre-version of the Power Point assignment, more than 160 responses were generated for the first question. This is an approximation since several thoughts could be in one response. This also applies to the responses to the other three questions with the overall comments being slightly less than for the first one. Table 3 shows a summary of the responses with number of responses are indicated in parentheses. Since these students are self-selected for this course, these responses may not necessarily represent the overall population of students majoring in Mechanical Engineering at Ohio State.

Question	Main Categories	Themes	Comments
	<u>Content Focused</u> Thermodynamics (11) Physics (11) Math (11) Manufacturing (10) Materials (10) Fluids (8) Mechanics (6) Statics/dynamics (5) Movement/motion (5) Science in general (5) Machine related (4) <u>Other Content Areas</u> Robotics, automotive,	Heavier emphasis on content than processes Recognition that Mechanical Engineering is a broad field combining many things Design importance is evident in responses	Comments reflect where students are in the Kolb[13] sense of development Many elements - communicating, work in teams, planning etc. - are not so apparent Students aware of what a Mechanical Engineer would have to know technically/content wise Broader view of Mechanical

What is Mechanical Engineering?	biomedical, aerospace, electronics, construction, computer programming, assorted topics (14) <u>Processes</u> Design (19) Design related to real world problems/efficient effective tools/practical problem solving (7) Problem solving, creativity, open-minded, etc. (7) Working in teams, analyzing data to make decisions, strategic planning, communicating, etc. (7) How stuff works (4) <u>Other</u> Public safety, benefitting society (3) Numerous mention of Mechanical Engineering being a broad field (approximately 6)	Lots of stress on Mechanical Engineers as leading to practical solutions to problems Areas missing – nano-technology, sensing systems, etc. Students kept coming back to creative problem solving Not for all, but for a portion social good was included	Engineering than gears and motors Across some comments is the idea of enhancing society via Mechanical Engineering Students see Mechanical Engineering as a broad applied field combining areas of content and process
What does a	<u>Highest areas cited</u> Design tools/products, machines/mechanical systems (21) R&D, invent, build new innovations (11) Manufacturing processes (11) General problem solving (10) Testing/analysis (10) Calculate reliability, efficiencies, etc. (4)	Problem solving Measuring concepts emerge Design remains prominent Design tied to specific areas Bio-Mechanical	Value of design for a variety of reasons was highly important R&D and coming up with new ideas was valued The idea of testing and careful measurement was prominent Concentrated on a small set of areas but not surprising as they are second year

mechanical engineer do?	More specific areas Design automotive & other forms of transportation (7) Work on energy systems (6) Improve products via design (5) Design biomedical devices & robotics (6) Other areas Administer, manage, work in teams (9) Sales & education in tech fields, teach (3) Consulting & troubleshooting (7) Safety, improve quality of life (5) Assorted other responses (8)	Engineering surfaces Sense of some non-engineering areas appear	students Students are recognizing multiple aspects to Mechanical Engineering outside of technical part
Advantages of Mechanical Engineering	Prominent responses In demand field, "sweet" job (21) High pay (19) Leads to numerous career paths, broad field (12) On leading edge (9) Rewarding - deals with real problems/solutions (9) Distinguished profession (3) Other responses Versatile profession with opportunities for growth	Awareness of what Mechanical Engineering is and where it takes them career wise Building from Mechanical Engineering base Applied dimension Appreciation of the field and where it could	The awareness of the students is quite good – they are hip Some at this point may think of other fields or the idea of spring boarding

	(11) Working with a team (4) Working with your hands (4) Challenging courses – personally rewarding (4) Fun, cool, why not (3) Assorted others (10)	take a person Field fits a number of students	 In persistence theory (Prenzel[14]), the concept of challenge is important
Disadvantages of Mechanical Engineering	Academics Demanding courses, time consuming, time to degree, addiction to caffeine, concepts to master (29) Highly competitive job & school environment (13) Math and hard sciences (11) Too many specializations to choose (3) Uninteresting classes/foreign profs (4) Non-Academic Stigma of being anti-social, too few females, limited social life, difficult to meet people out of classes (10) Not for you (2) Work Jobs may be more than 40 hours, job pressure (6) Comments about work – desk jobs, budgets, team work, lack of cutting edge, non-engineering etc. (8) Assorted others (8)	Academic demands, but students not seem surprised by them Lack of time for social life Competition Social issues and demands of field are real for students Some of the above themes carry over to work	Working with students to sort and balance conflicts is tricky yet vital May require looking at help mechanisms for juggling life and school (many are in place – review and reexamine) Stereotypes of engineers and social environment are concerns of students Lots of these concerns, including prior preparation, are potential areas for Mechanical Engineering faculty and support staff to examine

Table 3. Summary of Responses to the Pre-Power Point Assignment

Based on the responses in the table, students are aware of the Mechanical Engineering field and its broad landscape. The results indicate that the respondents:

- understand what the field is and what mechanical engineers do

- may not know all of the areas of Mechanical Engineering so they are somewhat concentrated on what is traditional
- recognize the versatility of the field and how it can take one in many different directions – they perceive Mechanical Engineering as being a very broad, encompassing discipline
- have a perception of the many areas of content that Mechanical Engineers need to know
- see the importance of design, designing products/processes, and the practical aspects of Mechanical Engineering
- have a sense of social concern and welfare with the idea being that products are being developed or improved for the public good
- feel that teams of engineers will have to work together to produce solutions to problems

In regard to "what do Mechanical Engineers do?", the answers dealt with activities cited below. They included:

- engineers have to design products and processes
- research and development is important to the field
- design and problem solving are key
- working with one's hands is important (15-20% of respondents inferred or stated this)
- testing, efficiency, cost-related issues, etc. are part of the job (in terms of product safety)
- engineering requires other skills such as managing projects, administration, working in teams, selling products and procedures
- consulting and troubleshooting

For the question "what are the advantages of Mechanical Engineering?", numerous points were made by the students. They are:

- financially rewarding
- great employment demand
- challenging field
- deals with real problems and solutions
- versatile and broad field that can lead to many different careers
- opportunities for growth
- allows one to working in teams
- very hands-on

The last question dealt with "what are the disadvantages to Mechanical Engineering?" Many comments about this question were made as follows:

- Concerns about hard and demanding coursework, time consuming aspects of studying to become a Mechanical Engineer, competition in school, time to degree completion, etc.
- Similar concerns about coursework in the sciences and that Mechanical Engineering depends on learning a lot of math and complex concepts and having to cut across so many fields
- Students like the versatility and broadness of the field as well as what they are being prepared for but the intensity of the time demands and course take their toll
- A small number of students mentioned problems of choosing specializations
- A few comments about uninteresting courses and international profs being hard to understand
- About half the students noted a highly competitive academic environment or perceptions of same
- The above point is in parallel to observations about the workplace
- Some jobs were perceived as being more than 40 hours per week and being very competitive (the idea is that the grind of undergraduate schooling would somewhat be akin to the workplace – more of same)
- Some jobs may not be too exciting (not on the cutting edge, desk work ….)
- About 40% of the students expressed issues with the social context of Mechanical Engineering (constant grind of an intense curriculum, time pressures, lack of females in classes, etc.)
- Students value what they are learning but not pleased about all they have to do

The Focus Group Interviews revealed important student perceptions of the course objectives, course flow and work load. There was an initial perception which grew consistently throughout the quarter that the primary or even sole objective of the course was the machining and assembly of the air motor. As a result, the curricular elements related to other objectives of the course were not received as well as they might have been. The functional decomposition, product teardown, design persona, and Gantt chart elements appeared to most of the students to be disconnected and "herky-jerky" in their presentation and flow. In the end-of-term focus group, there were suggestions on how to make some of that material fit in better with the air motor project.

It was clear that the students appreciated the hands-on experiences that gave them a sense of scale and proportion of physical dimensions, force, and torque. They found value in the introduction into the concept of manufacturability. They also were very excited about the machining skills which they acquired. The students were a good barometer - letting the instructors know that this first plan for the air motor was too ambitious from a machining standpoint. Their input in the midterm focus group led to a streamlined version of the project for the next term. The students also gave valuable recommendations for the organizational aspects of the machining project. They recommended that when the course moves to full scale enrollment by all students in the major there need to be a more systematic way to get students to learn the machines, obtain consistent guidance through the various tasks, and allow the students to plan and work on their own. They also recognized that the semester schedule will, in general, allow more time for the design, machining, and assembly of the motor.

The students got important first-hand experience in the challenges of working on a successful team. While some felt that there could have been more guidance in teaming, they also recognized the need for the students to work it out themselves. However, they uniformly agreed that when going to full scale, teaming will probably have to be dealt with a more systematic way. All in all every student appreciated this chance to participate in the pilot, felt empowered and involved in the course development and refinement, and appreciated the uniqueness of the experience compared to the rest of the curriculum.

Discussion and Current Work

Students in the course completed all evaluations in relatively high numbers. The pre Power Point assignment generated 500 - 600 responses (most in short bulleted points and some longer). Every student responded to all questions asked. The method worked well and the students had suitable experience with Power Point to do the evaluation. There are drawbacks that students can research answers to questions rather than speaking from their current viewpoint and the analysis of an open-ended procedure is more time intensive than a scaled approach. For the purposes of this beginning initiative for the design course, the procedure seemed appropriate. For the next term, students will be asked to handwrite a Power Point presentation during class so there isn't the opportunity to do research.

For the post Power Point assignment, there were few changes made but this seems reasonable in that it was self-selected group that was highly aware of what the field is and knew it coming in – hence initial responses required few modifications.

Two separate FGIs were held at the midpoint and at the end of the quarter, respectively. Each was led by the evaluator and a faculty facilitator (a non-instructor of the course). Two independent groups of students participated and there was enough time between the two meetings to assume that possible contamination was not a factor. Interviews lasted from 1 hour and 45 minutes to 2 hours and the discussion was lively and limited probing was needed on the part of the two leaders.

One indicator of validity is that through independent replication, many of the themes were in common. This does reaffirm the findings although it should be noted that since the timing in the quarter was different, the intensity and perspective on some responses varied intensity and nuance.

At the time of this writing, the second pilot course is being run. The focus of the pilot is for students to fabricate and assemble a six cylinder radial air motor. Each student will be responsible for fabricating two motors and they will work in teams of three to assembly the radial motor. Students will also use an Arduino microcontroller to adjust air flow to the motor.

Conclusions

Due to a conversion from quarters to semesters, the Department of Mechanical and Aerospace Engineering at The Ohio State University has embarked on an effort to revamp and enhance its design sequence. As part of this conversion, a new design course has been for second year students admitted to Mechanical Engineering. The objectives are two-fold: (i) to enhance student's foundational knowledge, skills, and associated intuition, and (ii) to introduce the students to open–ended design problems. Students will work in teams to construct a compressed–air motor and program an Arduino microcontroller to control the inlet air pressure to the motor. Then each team will design and prototype a device that will be driven by the output shaft of the motor. The overriding challenge of this course is the approximate 200 students per semester will take this new design course. Two pilots of the new design course will be completed before the semester implementation in Fall 2012. Assessment instruments of the pilots include assignment rubrics, focus groups, surveys, and questionnaires. This paper includes some of the preliminary data collection and results and issues encountered by the development team.

Appendices

A. Power Point Assignment

B. Overview of the Focus Group

C. Summary of Final Course Evaluations

Bibliography

1. Clayton, Garrett, et al. "Introduction to Mechanical Engineering - A Hands-On Approach." 2010 Annual ASEE Conference. 2010. AC 2010-1048.

2. Vaughan, Joshua, et al. "Using mechatronics to teach mechanical design and technical communication." Mechatronics (2008): 179-186.

3. Hargrove, Jeffrey B. "Curriculum, equipment and student project outcomes for mechatronics education in the core mechanical engineering program at Kettering University." Mechatronics (2002): 343-356.

4. Bannerot, Richard. "Hands-on Projects in an Early Design Course." ASEE Annual Conference and Exposition. Pittsburgh, PA, 2008.

5. Starkey, John M., et al. "Experiences in the Integration of Design Across the Mechanical Engineering Curriculum." 1994 Frontiers in Education Conference. 1994. 464-468.

6. Tsang, Edmund and Andrew Wilheim. "Integrating Materials, Manufacturing and Design in The Sophomore Year." Proceedings of the Frontiers in Education Conference. Atlanta, GA, 1995. Session 3c4.

7. Gabiele, Gary A., et al. "Product Design and Innovation: Combining the Social Sciences, Design, and Engineering." American Society for Engineering Education Annual Conference & Exposition. Salt Lake City, UT, 2004.

8. Spangler, Dewey and Kimberly Filer. "Implementation of Tablet PC Technology in ME 2024 Engineering Desing and Economics at Virginia Tech." 2008 Annual ASEE Conference & Exposition. Pittsbugh, PA, 2008.

9. Bilen, Sven G., Richard F. Devon and Gul E. Okudan. "Cumulative Knowledge and the Teaching of Engineering Design Processes." ASEE Annual Conference. Montreal, Quebec, Canada, June 16 - June 19, 2002. Session 2325.

10. Newell, James A., et al. "Multidisciplinary Design and Communication: a Pedagogical Vision." International Journal of Engineering Education (1999): 376-382.

11. Roemer, Robert, et al. "A SPIRAL Learning Curriculum in Mechanical Engineering." The 117th Annual Conference of the American Society for Engineering Education. Louisville, KY, 2010. AC 2010-1903.

12. Besterfield-Sacre, Mary, Larry Shuman, Cynthia Altman. "Pittsburgh Freshman Attitudes Survey". http://civeng1.civ.pitt.edu/~outcomes/

13. Kolb, David A., "Learning Style Inventory Manual", McBer, Boston, 1976.

14. Prenzel, M. "The selective persistence of interest" In K.A. Renninger, S. Hidi & A. Krapp (Eds.), Interest in learning and development. 1992. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers (71-98).

Appendix A. Power Point Assignment

What an honor! Your high school heard that you are entering the Mechanical Engineering program in the Department of Mechanical and Aerospace Engineering at The Ohio State University and invited you to talk to 9th and 10th graders at its future career day. They will be learning about engineering, education, nursing, allied health professions, business, and other fields. The idea is not to recruit but to acquaint students with the Mechanical Engineering profession from your perceptions of it. There are no wrong answers, so please be frank and honest.

For this activity,
1. Briefly design the title page of your Microsoft Power Point presentation with your name and title. (Slide 1)

2. Design Power Point slides with titles such as those similar to those shown below:

a. Slide 2. What is mechanical engineering? List up to five key areas of technical content.

b. Slide 3. What do mechanical engineers actually do? List up to five tasks.

c. Slide 4. What are the advantages of pursuing a career in mechanical engineering?

d. Slide 5. What are the disadvantages of pursuing a career in mechanical engineering?

Appendix B. Overview of the Focus Group

We are delighted that you agreed to participate in the focus group discussion of the new design course for second year students in Mechanical Engineering. As a student you have unique views of its content, structure, and implementation. There are no right answers, only your open and honest thoughts and comments. Please be frank as your ideas will be kept confidential.

A short introductory activity (some interesting about yourself or a recreational activity you enjoy) will get us on a first name basis. Then we'll explore topics such as those listed below so think about them a bit before we get together.

The organization and content of the course to date

The idea of basing instruction on a real world, open-ended problem

Your feelings about the positives and negatives of working in groups or teams

What you feel you have learned

Ways to improve the course

Other concerns as may arise

Dr. James Altschuld, a retired Ohio State University faculty member (not from any area of engineering) will lead the group. (Note: Dr. Dan Mendelsohn from the Department of Mechanical and Aerospace Engineering will assist with aspects of the discussion as necessary.)

Looking forward to a lively interaction.

Appendix C. Summary of Final Course Evaluations

Lectures	Enjoy			Learn		
	Mean	Median	Mode	Mean	Median	Mode
Engineering Design I: Thinking Functionally	3.7	4.0	4	3.9	4.0	4
Engineering Design II: Design Constraints	3.6	4.0	4	3.9	4.0	4
Technical Communication: Writing	2.5	2.0	2	2.8	3.0	2
Technical Communication: Sketching	3.8	4.0	5	3.5	4.0	3
Technical Communication: Prototyping	3.9	4.0	4	3.8	4.0	4
Managing Team Projects	3.4	3.0	4	3.2	3.0	3
Precision Measurement Techniques	3.3	3.0	3	3.9	4.0	5
Machining Logic	4.2	4.0	4	4.6	5.0	5
Computer Aided Design	4.0	4.0	4	3.8	4.0	4
Hole Making	3.5	4.0	4	4.3	4.0	4
Thermodynamic Cycles and Heat Engines	3.0	3.0	3	3.0	3.0	3
Fasteners	3.3	3.0	3	3.9	4.0	4
Air Motor Discussion	4.2	4.0	4	3.6	4.0	4
Technical Communication: Presenting Your Data	3.5	4.0	4	3.3	3.0	3
Technical Communication: Delivering a Talk	3.0	3.0	4	3.2	3.0	3
Conducting Yourself Professionally	3.7	4.0	4	3.5	4.0	4

Labs	Enjoy			Learn		
	Mean	Median	Mode	Mean	Median	Mode
Lab 1: Product Teardown	4.6	5.0	5.0	3.6	4.0	4.0
Lab 2: Performance Tests	3.9	4.0	4.0	4.0	4.0	5.0

Air Motor	Proficiency		
	Mean	Median	Mode
Milling	4.4	4.5	5.0
Turning (Lathe)	3.3	3.0	3.0
Fly Cutting	4.3	5.0	5.0
Drilling	4.7	5.0	5.0
Tapping	4.5	5.0	5.0
Boring	3.6	4.0	4.0
Reaming	3.8	4.0	4.0
Sawing	3.8	4.0	5.0
Filing	4.7	5.0	5.0
Belt Sanding	3.2	3.0	5.0

Assignments	Enjoy			Learn		
	Mean	Median	Mode	Mean	Median	Mode
Five Egg Design	3.3	3.5	5.0	2.8	3.0	3.0
Solidworks Tutorials	4.0	4.0	5.0	4.3	5.0	5.0