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A First-Year Introduction to Engineering Management Design Course

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Abstract

A two-semester first-year undergraduate course is offered as the introductory course in the engineering management major at Clarkson University. The course is open only to engineering management majors and has broad objectives that touch on many aspects of the major in an introductory fashion. It also touches several aspects of the ABET engineering criteria. The course is required of first-year students in the major. In the course students work in teams to perform two engineering designs. In the first semester the design is prescriptive and is used as a tool to teach and learn engineering design tools of Microsoft Excel, MathWorks MATLAB, and Autodesk Inventor, and the presentation tool Powerpoint. The students also learn basics of teaming, the engineering design process, the meaning of real world constraints, design for the environment, and ethics. The students present their designs in oral and written fashion at the end of the semester.

In the second semester, the design process is opened up to the teams and a real-world design is undertaken. The design in the second semester involves a local real world client and incorporates performing the engineering design and learning the basic tools of project management, supply chain management, and operations management to prepare a management plan around the project design. The product and management plan are again presented orally and in a written document and presented to the real world client. Some of the designs from this second semester course have been adopted by the client in recent years.

Course description

In the Proposed Changes to the 2016-2017 Criteria for Accrediting Engineering Programs, ABET defines engineering design as “the process of devising a system, component or process to meet desired needs, specifications, codes and standards within constraints such as health and safety, cost, ethics, policy, sustainability, constructability, and manufacturability. It is an iterative, creative, decision-making process in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally into solutions.” [1] This two-semester course strives to provide students with engineering design practice while learning the basic concepts of engineering management.

The course consists of a one and one half hour lecture period once per week to the entire class of students on topics necessary to engineering design and engineering management. There are also one and one half hour laboratory sections each week given to three separate sections in which students work in teams and at computers in a computer lab on tutorials and team design activities. In the first semester, the student teams are led through the process of engineering design to create a structured design. The students learn and use various engineering tools to design a set of medicine balls and a medicine ball rack to meet specific criteria for a commercial gym.

Engineering management majors at this university are also taking their math and basic sciences courses in their first year. They are general taking Calculus I and II, Chemistry I and II, Accounting, Enterprise Information Systems, Freshman English, and Psychology, along with this course.

In the first semester lectures, students learn about teaming and team management, the engineering design process, project management techniques, design for the environment, standards and regulations, engineering ethics, and receive instruction in technical writing and oral presentation using Powerpoint. Teaming is a section of the Leadership and Organizational Management domain as identified in the Engineering Management Body of Knowledge (EMBOK)[2]. The engineering design process and design for the environment are important to ABET and also a portion of the Management of Technology, Research and Development Domain in the EMBOK. Project Management represents an entire domain in EMBOK. Standards and regulations fall under the Legal Issues in Engineering Management Domain, and engineering ethics are a portion of the Professional Codes of Conduct and Ethics domain. Assignments in the course are about half individual and half team assignments. The team assignments sum together to create the final design and presentation. Lecture and laboratory activities for the first semester are outlined in Table 1.

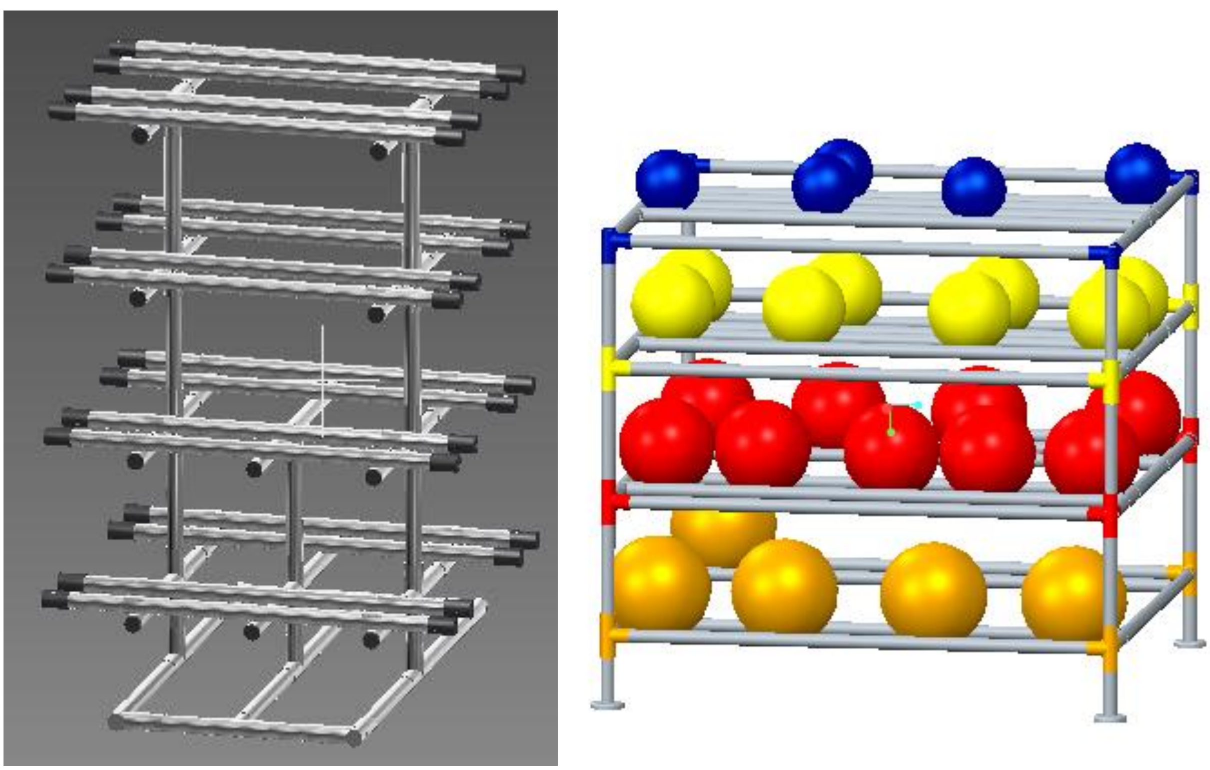
Table 1. First semester lecture topics and laboratory activities:

Week	**Lecture Topic**	**Laboratory Activity**
1	Course Introduction	Team-building Exercise
2	Team Management and Team Contract Preparation	Prepare Team Contract
3	Introduction to Engineering Design Process	Team Design Exercise using Engineering Design Process
4	Writing Instruction	Microsoft Excel Tutorial and Exercise
5	Introduction to MATLAB	Microsoft Excel Tutorial and Exercise
6	Break	MATLAB Tutorial and Exercise
7	Exam	MATLAB Tutorial and Exercise
8	Project Management	MATLAB Tutorial and Exercise
9	Design for the Environment	Design for the Environment Lab
10	Introduction to Autodesk Inventor	Autodesk Inventor Tutorial and Exercise
11	Standards and Regulations	Autodesk Inventor Tutorial and Exercise
12	Engineering Ethics	Autodesk Inventor Tutorial and Exercise
13	Exam	Work on Design
14	Introduction to Powerpoint	Work on Design and Presentation
15	Work on Design	Work on Design and Presentation
16	Work on Design	Team Presentations of Designs

In the laboratory and outside of class students perform exercises leading them to their final designs of the medicine balls and medicine ball rack. First students perform a design exercise in class in their teams. Then they learn to use Excel by solving a golf ball projectile analysis, learning Excel calculations and graphing. They then solve the same golf ball projectile analysis using MATLAB to learn the advantages of a programming language to manage multiple calculations. Students then use MATLAB to design the medicine balls. The balls are made of three materials, a sand core, held in a thin metal shell and covered with a rubber cover. The students use MATLAB to determine the material requirements and ball diameters necessary to make a set of balls that meet the given weight criteria. They have multiple materials (sand, metal, and cover materials) available to them and must choose and design the balls using the "best" combination of materials and meet the weight restrictions.

Using Excel and cost information given to them, the students perform a cost analysis of the balls and their construction. They then learn to use Autodesk Inventor and each student individually creates two computer-aided designs during Inventor tutorials. They also learn to create hollow pipe structures in Inventor. As a team they then design a medicine ball rack in Inventor that can hold the desired number of medicine balls, provide safe access to the balls, and fit into the desired space in the gym. The rack must be structurally sound and a minimum of ten percent of each ball must lie below the hold point on the rack in order to provide stability.

Figure 1 below shows two examples of the Inventor design of a medicine ball rack for a commercial gym.



In the second semester, the teams move to designing a product and manufacturing process for a real world client. This opens the design process and increases the real-world constraints on the design. The client for this project is a non-profit organization that serves developmentally disabled clients, St. Lawrence NYSARC. The clients perform some service activities such as janitorial duties at local businesses, document shredding, sorting of recyclables, or participate in day habilitation. It is a goal of St. Lawrence NYSARC to move more of the clients from day habilitation to employment activities.

The Javits-Wagner-O'Day (JWOD) Act appears in Title 41 of the United States Code, Sections 8501 through 8506 [3]. The JWOD Act allows for sole source supply to federal government agencies of products that are manufactured by a workforce in which at least 75% of the work-hours are performed by workers who are blind or developmentally disabled. A similar law in New York State allows the same to take place for state and local government agencies. They must purchase a product if it is manufactured at a non-profit organization and employs 75% disabled workers. Also in New York, another non-profit organization, New York State Industries for the Disabled (NYSID) serves as a distributor of the "preferred" products created by the local non-profit agencies. They provide a catalog of these products and provide the supply chain to get the products to the governmental agencies that purchase them.

St. Lawrence NYSARC and NYSID want the student teams to identify a product that would be used by state or local government agencies and that can be manufactured by disabled workers. The students determine a need where a product manufactured by the client could replace a product in use by state or local governments. They develop a product design to meet that need. They determine the manufacturing process for that product within the constraints of operation of the non-profit organization. They create a management and operation plan to demonstrate that the product will create jobs for workers and generate enough revenue to make the manufacturing process viable. Thus the project moves developmentally disabled people from being served in day habilitation at a cost to the agency, to working in manufacturing and being employed. It is not important that the product create a large revenue stream, but it must cover the operations of the facility and employ workers. Products that have been developed by student teams in the past include identification tags for uniforms, to-go boxes made from recycled paper, assembly and charging of fire extinguishers, and traffic cones with reflective tape. An illustration from the work of the student team that worked on the fire extinguisher project is shown in Figure 2.

Other products sold in this state through the "preferred" product process include personal care kits for prison intake, food service items, hard hats, personal protective equipment, and even specialty picnic tables for the state fair. The product designs developed by the student teams must meet standards and regulations and cannot impose on a patented item. The product also must not already be manufactured by another similar non-profit organization and thus be in competition for the spot in the "preferred" product catalog.

Figure 2: Student work on a plan to assemble and charge fire extinguishers at the non-profit agency.

In order to perform this design students must understand the “art and science of planning, organizing, allocating resources, and directing and controlling activities that have a technological component” [3] which is the definition of engineering management according to ASEM. Students are introduced to some of these topics in lecture and apply them in structured exercises in the laboratory, working either on example tutorials or on the actual design project. The lectures and laboratory activities for the second semester of the course are outlined in Table 2.

At the end of the second semester, each team has created a product and designed the manufacturing process for it, using project management tools, operations and supply chain management, and financial management. They have worked through ethical issues in choosing the product and in ensuring the product does not impose on another agency’s product. Students have learned to work in teams, and they have prepared and presented a management plan around their product. Though many of the student product designs in the end turn out to be impractical for various reasons, such as an impractical supply chain or failing to generate revenue in the pro forma financial plan, they have gone through the design process and applied engineering management principles to complete a design. As mentioned, the client has in the past implemented some of the student designs and is always hoping for another successful design to implement. The student engagement in the project is high as they see a real world application of their work and feel good about helping a local disabled population.

Table 2. Second semester lecture topics and laboratory activities:

Week	Lecture Topic	Laboratory Activity
1		Team-building Exercise
2	Course Introduction and Design Problem Presentation	Prepare Team Contract Brainstorm Questions for Client
3	Client Presentation and Q&A	Plan Project
4	Introduction to Microsoft Project / Gantt Chart	Prepare project Gantt Chart
5	Intellectual Property	Patent Search exercise
6	Exam	
7	Management Plan Process	Work on Design
8	Marketing Plan Process	Work on Marketing Plan
9	Organizational Plan	Work on Organizational Plan
10	Break	Break
11	Financial Resource Management	Guided Financial Plan problem in laboratory
12	Marketing and Sales Management	Work on Financial Plan
13	Supply Chain Management	Work on Designs
14	Operations Management	Work on Designs
15	Exam	Work on Management Plan
16	Work	Team Presentations of Designs to Client

Topics in the second semester lectures are also derived from parts of the EMBOK and/or from ABET outcomes. Students perform teaming as they prepare a team contract for the semester. They perform project management as they prepare a Gantt chart for their team project. Patents and Intellectual Property are portions of the Legal Issues in Engineering Management Domain. Marketing is a portion of the Marketing and Sales Management Domain. Lectures in this semester also touch on the Financial Resource Management and the Operations and Supply Chain Management domains.

Assessment

Some of the activities from the class make it easy to use as assessment tools. Assignments from the class are used in the program as one of the measures towards attainment of three ABET outcomes[4] within the program.

Final grades on the team design report from the second-semester of the course are used to measure outcome (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. Figure 3 displays the assessment rubric used in the course.

Final grades on the team oral presentation are used as a measure of (g) an ability to communicate effectively. Figure 4 displays the rubric used for this assessment.

Average scores on the individual assignments performed in Excel, Matlab and Inventor are used as a measure of (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. Figure 5 displays the three rubrics used for assessing the individual assignments in each of the software tools.

Conclusion

A two-semester first year introduction to engineering design and engineering management course is presented to all first year engineering management majors at this university. Students learn basic engineering design and are introduced to engineering tools and engineering management principles. They are engaged by the process as they see the possibility of real world implementation. Some course assignments can be used to aid in assessment of ABET Criteria.

References:

1. ABET. (2015) Proposed Revisions to EAC Criteria 3 and 5, retrieved from: http://www.abet.org/wp-content/uploads/2015/11/Proposed-Revisions-to-EAC-Criteria-3-and-5.pdf
2. Shah, H. (ed.). (2012) A Guide to the Engineering Management Body of Knowledge, 3rd edition. Rolla, MO: The American Society for Engineering Management.
3. U.S. Ability One Commission. (2015) Javits-Wagner-O'Day Act. Retrieved from: http://www.abilityone.gov/laws,_regulations_and_policy/jwod.html
4. ABET. (2015) Criteria for Accrediting Engineering Programs. Retrieved from: http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/#outcomes

Assessment Rubric – (c) ability to design a system, component or process that meets needs… Final Written Report

Process Engineering & Design | EM 456 | Spring 2015

Rubric	Percentage	Points	Wt. Score	Poor – 1 pt.	Average – 3 pts.	Excellent – 5 pts.
Design Process Completed	25%			Students have not completed the iterative process of recognizing a need, defining the problem, collecting useful information, conceptualization of several potential solutions, synthesis of these solutions, evaluation, optimization and presentation, as they have not considered several potential solutions or did not focus into a single solution.	Students have addressed all aspects of the iterative process of recognizing a need, defining the problem, collecting useful information, conceptualization of several potential solutions, synthesis of these solutions, evaluation, optimization and presentation such that some remaining work could result in implementation.	Students have addressed all aspects of the iterative process of recognizing a need, defining the problem, collecting useful information, conceptualization of several potential solutions, synthesis of these solutions, evaluation, optimization and presentation such that the design could be implemented directly, without further examination.
Design Meets Identified Needs	25%			The design does not conform to several of the identified needs or objectives.	The design meets most of the identified needs or objectives and makes reasonable attempts to meet the remaining needs or objectives.	The design meets all of the identified needs or objectives and exceeds minimum expectations.
Constraints Identified as Appropriate to the Design	25%			Students have not taken into account several realistic constraints applicable to the design such as economic, environmental, social, political, ethical, health & safety, manufacturability, and sustainability.	Students have identified several of the realistic constraints applicable to the design such as economic, environmental, social, political, ethical, health & safety, manufacturability, and sustainability.	Students have carefully identified all realistic constraints applicable to the design such as economic, environmental, social, political, ethical, health & safety, manufacturability, and sustainability.
Constraints Addressed as Appropriate to the Design	25%			Several identified constraints were not addressed in the design report.	All identified constraints have been addressed and incorporated into the report, but some are not met optimally, resulting in more effort needed to reach an implementable design.	All identified constraints have been appropriately addressed and incorporated clearly into the design report, resulting in an implementable design.
Totals	100%					

Assessment Rubric – (g) ability to communicate effectively
Oral Presentation
Technological Entrepreneurship | EM 121 | Spring 2016

Rubric	Percentage	Points	Wt. Score	Poor – 1 pt.	Average – 3 pts.	Excellent – 5 pts.
Content Relevance of topic, accuracy of material, overall treatment of topic	20%			Topic lacks relevance to design problem; presentation contains multiple fact errors or omissions	Topic is adequately focused and relevant; major facts are accurate and generally complete	Topic is tightly focused and relevant; presentation contains accurate information with no fact errors
Organization / Clarity Appropriate introduction, body, conclusions; logical ordering of ideas; transitions between points	20%			Ideas are not presented in proper order; transitions are lacking between major ideas; several parts of presentation are wordy or unclear; introduction or conclusion is undeveloped	Most ideas are in logical order with adequate transitions between major ideas; presentation is generally understandable	Ideas are presented in logical order with effective transitions between major ideas; main points well stated and argued; presentation is clear and concise
Completeness Level of detail, depth; appropriate length; adequate background of information	20%			Presentation does not provide adequate depth; key details are omitted or undeveloped; presentation is too short or too long	Presentation provides adequate depth; few details are omitted; major ideas adequately developed; presentation is near appropriate length	Presentation provides good depth and detail; ideas are well developed; facts have good background; presentation is within specified length
Grammar and Vocabulary Correct grammar and usage that is appropriate for the audience	10%			Presentation contains more than a few grammar or usage errors; sentences are incomplete or contain excessive jargon	Presentation contains has few grammar and usage errors; mostly jargon-free; complete and understandable	Presentation contains no grammar or usage errors; free of jargon; complete and easy to understand
Documentation Proper support and sourcing of major ideas; inclusion of visual aids that support message	10%			Little or no message support provided for major ideas; visual aids are missing or inadequate; little or no sourcing provided	Some message support provided by facts and visual aids; visual aids need work	Effective message support provided in the form of facts and visual aids; visual aids are creative and interesting; sourcing is current and supports major ideas
Delivery Adequate volume; appropriate pace, diction; personal appearance; posture; effective use of visual aids	10%			Low volume or energy; pace too slow or too fast; poor diction; distracting gestures or posture; unprofessional appearance; visual aids poorly used	Generally effective delivery; pace slightly slow or fast; few or no distracting gestures or posture; professional appearance; visual aids used adequately	Good volume and energy; proper pace and diction; avoidance of distracting gestures; professional appearance, visual aids used effectively
Interaction Adequate eye contact; ability to listen and answer questions	10%			Little or no eye contact with audience; poor listening skills; uneasiness or inability to answer questions	Fairly good eye contact; generally aware of the audience; displays ability to listen; provides adequate answers to questions	Good eye contact with audience; excellent listening skills; answers questions with authority and accuracy
Totals	100%					

Figure 5.

Grading Rubric for Individual Assignment 2: Excel Golf Exercise

Points Awarded	Points Possible	Requirement
	1.0	Used Excel as a tool
	1.0	Used Excel Solver to find y=0
	0.5	Velocities 25 to 45 m/s
	0.5	Angles 25 to 55 degrees
	1.0	Graph appropriate material
	1.0	Graphs correctly labelled
	5	**Final Score**

Grading Rubric for Individual Assignment 3: MATLAB Golf Exercise

Points Awarded	Points Possible	Requirement
	1.5	All deliverables submitted (1 plot per swing speed and .m file)
	1	All graphs are properly labeled (title that includes swing speed, x and y axis labels that include units)
	1.5	Running the submitted .m file performs all calculations and generates all plots (with all curves, labels, and legend)
	0.5	Legend on every plot that correctly identifies each curve according its associated loft angle
	0.5	Every line of code is appropriately commented
	5	**Final Score**

Figure 5 continued

Grading Rubric for Individual Assignment 5: Inventor Water Bottles

Points Awarded	Points Possible	Requirement
	1	All deliverables submitted (6 total files: 2 assemblies and 4 parts)
	1	Correct geometry and dimensions for cap and bottle part files from Inventor tutorial
	0.5	Properly constrained assembly for tutorial water bottle
	1	Correct geometry and dimensions for prototype water bottle
	1	Correct geometry and dimensions for prototype bottle cap
	0.5	Properly constrained assembly for prototype water bottle
	5	**Final Score**