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INTEGRATIVE MULTIDISCIPLINARY MATERIALS & MECHANICS TEAM PROJECT

Dr. Kyle G. Gipson, James Madison University

Dr. Kyle Gipson is an Assistant Professor at James Madison University (United States) in the Department of Engineering (Madison Engineering) and the Center for Materials Science. He has taught courses pertaining to introduction to engineering, materials science and engineering, engineering design and systems thinking. He has a PhD in Polymer, Fiber Science from Clemson University. His research background is in the synthesis of polymer nanocomposites and engineering education. He was trained as a Manufacturing Process Specialist within the textile industry, which was part of an eleven-year career that spanned textile manufacturing to product development.

Dr. Robert J Prins, James Madison University

Robert Prins received his Ph.D. in Mechanical Engineering from Virginia Tech in 2005; he is currently an associate professor in the Department of Engineering at James Madison University (JMU). Prior to joining JMU, Dr. Prins was a faculty member at Virginia State University. Dr. Prins' industrial experience includes one year as a suspension engineer at Visteon, Inc. and five years as an engineer at Perceptron, Inc., a machine vision company.

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Abstract

The multi-disciplinary engineering program at James Madison University includes courses that integrate topics that are traditionally taught as stand-alone courses. This offers a unique opportunity to draw student attention to the interdependency and interlinking between topics. One such course, ENGR 314: Materials and Mechanics has evolved from its initial casting as two partial courses into a more integrated presentation. The primary integrating factor is a semester-long design project that requires students to use concepts from the entire course to design an artifact. The integrative nature of the project as well as the nature of the final presentation combine to provide students with an experience that they perceive as valuable and authentic.

Introduction

In order to provide context for the semester-long Mechanics and Materials integrative project we offer the following brief descriptions of the university, program, and course in which the project resides.

James Madison University

James Madison University is a public regional university located in Harrisonburg, Virginia with a total enrollment of approximately 20,000 students across all of its seven colleges containing approximately 1,700 of those students enrolled in a graduate program. The College of Integrated Science and Engineering was established in 2012 when the departments of Integrated Science and Technology and Computer Science merged with the School of Engineering. The School of Engineering now exists as the Department of Engineering (Madison Engineering).

Madison Engineering

Madison Engineering was founded in 2005 with the first cohort of students starting in fall of 2008. It was designed to be a non-discipline specific progressive engineering program unrestricted by the boundaries of traditional engineering disciplines. The program was proposed based on the following description of the Engineer of 2020 by the National Academy of Engineering: one who possesses strong analytical skills, strong communication skills, a strong sense of professionalism, creativity, and versatility[1,2]. The 126 credit hour program is ABET accredited (10/01/2011 – present) under the Engineering Accreditation Commission (EAC) where most students complete the degree in four years. The program has a current enrollment of approximately 450 students as of August 2014.

The Madison Engineering program was established to train the engineering versatilist. Engineering versatilist is a phrase invented by Garner, Inc. and popularized by Friedman that described an individual who can "apply depth of skill to a progressively widening scope of situations and experiences, gaining new competences, building relationships, and assuming new roles" (Friedman, 2005, p. 291)[3]. The program includes sustainability emphasis that attempts to engage students with the awareness of how and why a diversity of values, viewpoints, and actions might assist them in developing into flexible, creative practitioners, with the capacity to enact sustainability in a diverse array of future professional contexts[4]. Additionally, the program includes many opportunities for experiential education in the form of labs and hands-on projects. We consider a Madison Engineer to be alumni that successfully combine these attributes.

ENGR 314: Materials and Mechanics

Materials & Mechanics is a four credit hour lecture/laboratory core (required) course within the Madison Engineering curriculum. ENGR 314 is generally taken in the junior year and was created to provide students with a working foundation for exploring the governing principles of materials science and the mechanics of materials. Typical class size is 25 students per section with two sections running per semester.

The course has four major topic areas as shown in Figure 1[5]:

- Characterization of Mechanical Properties
- Analysis of Structural Elements
- Material Properties and Structure (Science-led Approach)
- Life Cycle Thinking and Eco-audits (Design-led Approach)

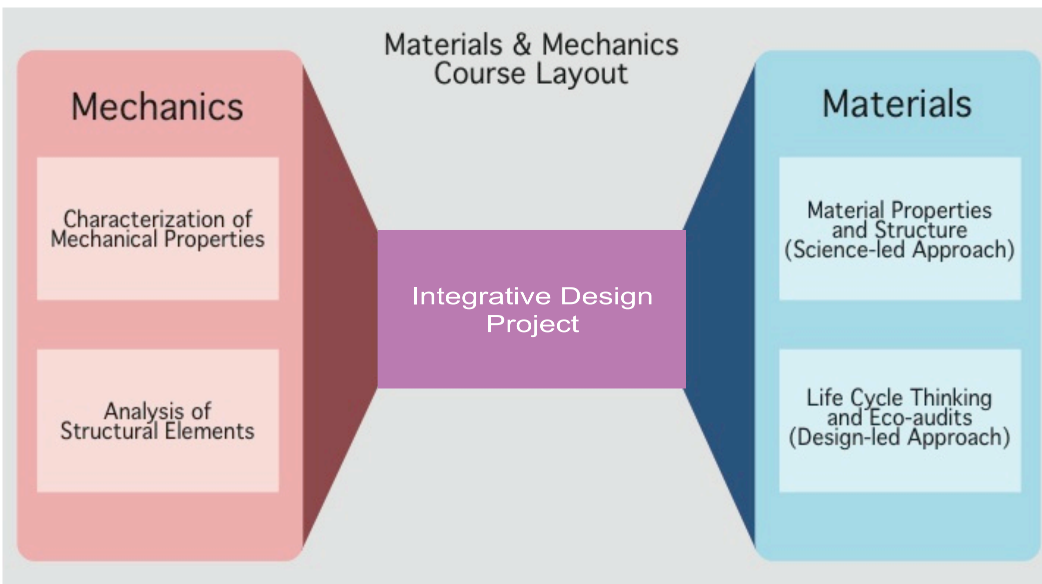

Figure 1. Course layout of Materials & Mechanics course[5]

Materials & Mechanics is a multidisciplinary course that provides students with traditional content components from materials science and mechanics of materials. The Mechanics portion allows students to advance their knowledge about loads on physical structures in the Analysis of Structural Elements component while gaining hands-on testing and analysis experience in the Characterization of Mechanical Properties component. The Materials portion guides the students through science-led (investigations of scale, composition and quantity) and design-led (product development focused on performance) approaches to materials selection[6]. The course also includes a semester long design project which integrates course topics. Currently, the teaching team is comprised of two faculty members, one with education and experience in the field of mechanical engineering (Prins: mechanics), and the other with education and experience related to materials (Gipson: materials). The course faculty for all sections has been mostly consistent from FA11 - SP14 (with exception of Dr. Elise Barrella: mechanics in SP13). In FA14 a visiting faculty member taught one section of the course using a different approach and information from that section of the course is not addressed in this paper. The following sub-sections provide additional descriptions of the Mechanics and Materials content respectively[5].

Mechanics

The Mechanics portion of the course spans seven weeks and includes lecture and laboratory content related to Characterization of Mechanical Properties and Analysis of Structural Elements. Certain components of traditional coverage, including stress elements, principle stresses, and Mohr's circle analysis are not covered in ENGR 314, rather, they are covered in a following elective course (ENGR 498: Solid Mechanics).

Characterization of Mechanical Properties
Topics in the area of Characterization of Mechanical Properties include lectures on stress-strain curves and laboratory exercises related to tensile testing, three point bend testing, and hardness testing. The testing and analysis methods learned in the three laboratory exercises mentioned above occur early in the first seven weeks of the term and prepare the students to run independent tests in support of their project.

Analysis of Structural Elements
Topics related to Analysis of Structures include lectures on bending stress (includes coverage of shear and moment diagrams and sectional properties), columns, deflection of beams, and torsion in shafts as well as laboratory exercises related to use of computer aided design (CAD) packages to determine sectional properties, and use of a strain gage in the calculation of bending stress.

Materials

The Materials portion of the course spans eight weeks and is a fusion of both science-led and design-led approaches to material selection. Included in the materials portion are the following topics: process-structure-property relationships, crystalline structures, material properties, design process, failure mechanisms, and product development. Introduction to the following subject matter is also contained within the materials portion of class: material selection strategy, materials processing, sustainable design concepts, ecological audits, evaluating analytical data and rapid prototyping (additive manufacturing).

Material Properties and Structure (Science-Led Approach)
The content delivered via the science-led approach informs the students about the interconnectedness of structure, properties, processing and performance of materials in products. Four types of engineered materials (metals, ceramics, polymers, and composites) are introduced along with the associated major properties (mechanical, thermal, electrical, optical, magnetic, and chemical/deteriorative) for each material. The properties are then shown to be associated with the internal components (structure) of the material. To

understand the behavior of the materials the focus shifts to how materials respond to stimuli and the characteristics resulting from the response by exploring the six major material properties. Techniques to evaluate materials properties are covered in an elective course (ENGR 498: Materials Characterization) which is part of the materials science minor offered through the Center for Materials Science at James Madison University.

Life Cycle Thinking and Eco-audits (Design-Led Approach)

The laboratory topics are discussed from the design-led perspective in order to evaluate the trade-offs that are associated with selecting a material for a desired application. Within this domain, students build upon a developmental platform for life-cycle and systems thinking through "breaking down" the life cycle of two similar products into life-cycle stages. Students then perform ecological impact audits (Eco-Audit) within the CES EduPack to evaluate selected materials based on potential environmental implications such as embodied energy and carbon emissions (CO_X)[7].

Integrative Design Project

Although the Materials & Mechanics Integrative Design Project (project) has evolved over time, significant characteristics have remained constant so that a general description is possible. The project integrates concepts from the backdrop of the course within a real-world scenario. The inspiration of the real-world scenario is largely due to the prior industrial experiences of the teaching team. The project requires students to extend the theories and methods learned in the course in order to design an artifact with certain criteria and to provide ample justification for the actions taken to develop the prototype. The students are instructed that they will be fulfilling the roles of recently hired members of the Research and Development Department of the fictitious "GP"company. The students investigate selected materials and justify decisions with evidence collected by testing and analysis. The final deliverables of the project are a written report and a presentation in front of a panel representing the management team where the students give recommendations to fund or not to fund the project in a particular direction.

Integrative Design Project Background Information

The project requires teams of up to four students to design an artifact using materials from their assigned material family (metal, plastics, ceramics, or composites). The project is open ended in that the shape, testing protocols, and the material (other than broad family) are not specified. This presents students with sufficient ambiguity that they must make decisions and assumptions in order to scope their design space. Assessment of the project includes an evaluation of how well they document and support their decisions and assumptions.

Conceptualization to Material Selection Analysis

Students must consider the translation of customer desires into functional attributes for the purpose of selecting materials that will yield a valued and sustainable final product. Based on functional attributes identified, students determine the properties that need to be limited or maximized within the selection process. Teams are instructed to evaluate each material through the lens of societal, economical, environmental, and technical factors. Teams must also consider the lifecycle of the material when evaluating the materials' overall impact.

Presentation (Oral Examination) & Debrief

Each team has to prepare and give a fifteen-minute presentation that showcases what they have done to produce a design. The presentation component is a unique feature to the project and our program due to the interaction between presenters and panelists. A panel of faculty, staff, and students are encouraged to interrupt the presenters to ask questions based on the content presented. The students are instructed that all the members of the team should understand anything that is said or shown on a slide by themselves or their fellow team members. The "gloves off" approach employed by the panel provides the mood of an oral examination.

Evolution of the Integrative Project

Although the project was initially instituted to integrate concepts from the materials portion of the course, it has evolved into the primary integrator of materials and mechanics content within the course. The teaching team that has taught nearly all sections of ENGR 314 from FA11 through SP14 is comprised of two faculty members (the authors). The one exception occurred in SP13 in which Dr. Elise Barrella taught the mechanics portion of the course. This has provided a stable environment for the course which has promoted further development and evolution of the project.

Project history begins in FA11 when the authors first began co-teaching the course. The motivation for the introduction of the project was to provide students with a simulated practical industrial experience in which students apply science fundamentals in a design domain. The project exercise presented an opportunity to demonstrate the connections between different concepts such as materials properties, processing, characterization techniques, the use of engineering software tools, and ecological impacts. Table 1 is presented to illustrate the evolution of the project over the three and half academic year time period. Over time the project went through changes in two realms: a design artifact realm and an expectation realm. The design artifact was initially a beverage container but was changed to a shelf in order to better accommodate mechanics content. Project expectations came into focus over time as the teaching team evaluated student work. Changes in expectations are captured in changing content requirements. Furthermore, the teaching team customized communication with individual student teams to highlight gaps between student work-in-progress and expectations.

Table 1. Evolution of the Integrative Project (2011-2014)

Semester	**Artifact**	**Length**	**Value**	**Expectations**	
				Content	**Communication**
FA11	Beverage Container (5L - carbonated beverage)	8 weeks	8%	-Identify 3 materials with in material family -Material selection evaluation through material properties, processing, sustainability (environmental, societal,	• Preliminary Written Report – reports graded with feed back supplied in the report • Final Written report – graded

				economical, & technical factors) -Ecological audits -Material testing -Statistical analysis -Deliver information in written and oral formats	• Presentation Final – Rubric A
SP12	Beverage Container	15 weeks	8%	Preliminary Evaluation (PE) -Identify 3 materials with in material family -Material selection evaluation through material properties, processing, sustainability (environmental, societal, economical, & technical factors) -Ecological audits -Deliver information in written format Final Evaluation (FE) All that was in PE plus the following: -Material testing -Statistical analysis -Design a material test procedure -Deliver information in written and oral formats	• Preliminary Written Report – Comment Sheet • Preliminary Presentation • Final Written report – Rubric B • Presentation Final – Rubric C
FA12	Beverage Container	15 weeks	8%	PE & FE Same as SP2012	• Preliminary Written Report – Comment Sheet • Preliminary Presentation • Final Written report – Rubric B • Presentation Final – Rubric C
SP13	Beverage Container	15 weeks	8%	PE & FE Same as SP2012	• Preliminary Written Report – Rubric D • Preliminary Presentation – Rubric E

					• Final Written report – Rubric B • Presentation Final – Rubric C • Project Debrief
FA13	Beverage Container	15 weeks	10%	PE Same as SP2012 FE same as SP2012 plus: -3D printed prototype -Economic feasibility study	• Preliminary Written Report – reports graded with feed back supplied in the report • Project Consultation & Container Drawing Approval • Final Written report – Rubric F • Presentation Final – Rubric F • Project Debrief
SP14	Shelf	15 weeks	18%	Conceptual Portfolio (CP) -Draft drawings (CAD) -Free body diagrams and loading analysis -Material processing evaluations -Ecological audits -Documentation of material selection process -Deliver information in written format Final Portfolio (FP) All that was in CP plus the following: -Mechanics & materials selection analysis -Material testing -3D printed prototype -Assembly instructions -Statistical analysis -Deliver information in written and oral formats	• Project Consultation I • Conceptual Portfolio – Rubric G • Report Consultation with the Writing Center • Project Consultation II • Final Portfolio – Rubric H • Project Debrief
FA14	Shelf	15 weeks	20%	CP & FP Same as SP2014	Same as SP2014

The first iteration of the project in FA11 was primarily focused on materials selection. Students were given eight weeks to select three materials from an assigned family of materials to test based on the six material property domains of solid materials. They also had to assemble data to justify decisions that were discussed and reviewed through the report and the oral examination. The latest iteration of the project (SP14 and FA14) includes the elements of the first iteration as well as sustainability and mechanics analyses. It is further characterized by faculty consultations with teams before critical deliverables and an increase in value (percent of student course grade) from 8% to 20%.

Artifact Realm

The initial design artifact (beverage container) was selected because of its' presumed familiarity to the students. Students were introduced to the progression of beverage containment throughout history and more specifically carbonate beverage containment. Carbonate beverage containers also offered a reasonably rich design space (materials from all four families of materials have been used to contain beverages) that includes such considerations as form (physical dimensions and how those relate to shipping, merchandising, and end user interactions) and function (chemical interaction between contents and container, heat transfer properties of container and potential impacts on contents, response to light of the container and potential impacts on contents and influence of container on branding). Due to a persistent desire to further integrate the mechanics portion of the course with the materials portion of the course, the instructors (the authors and a colleague, Dr. Elise Barrella) discussed changing from a beverage container to a different design artifact that would readily accommodate the Mechanics analyses covered in the course. Proposed artifacts included a chair, a table, and a bookshelf. The instructor team ultimately chose a shelf unit of unspecified usage to allow more freedom within the design domain.

The shelf unit still allowed the project to be open-ended where the teams had to create a design and develop a new shelf system made from materials within an assigned material family. Teams were advised to create virtual and physical prototypes, assembly instructions, and to provide justification for the specifications of the proposed shelf unit. After the teams narrowed down the material choices within their assigned family they had to perform physical material testing on samples. The proposed test strategy had to be pre-evaluated in regards to safety, equipment compatibilities, and sample delivery. Teams conducted tests as before to understand the response of the materials under a load or force, electrical field, energy (heat), magnetic field, electromagnetic or light radiation, and chemical stimulus.

Changing the artifact to a shelf allowed students to readily apply mechanics analyses including shear and moment diagrams, beam bending stress, simple shear stress, and beam deflection. Although more novel solutions have been developed, a representative solution includes a planar shelf that rests on supports that extend from the wall: this makes a good case to consider from the perspective of what analyses the teams typically provide. The shelf itself is modeled as a uniformly loaded simply supported beam and analyzed for stress and deflection. The supports are modeled as uniformly loaded cantilever beams and analyzed for stress and deflection. Fasteners that mount the supports to the wall are analyzed for shear stress and their interface with the wall is analyzed for pull out strength. The range of analyses required for a representative solution demonstrates the richness of the mechanics aspect of the project.

Expectation Realm

Initial expectations were rudimentary: students would apply the science they had learned to an open-ended material selection problem and come to a defendable decision. As the instructors observed student responses to the design brief their expectations became more specific. Other changes to expectations came from additions to course content that were then integrated into the project. Expectations were initially communicated via the design brief and grading rubric. Over time faculty instituted "consulting sessions" in which each professor met with each team to review submitted material and communicate gaps between student work and expectations.

Content

With exceptions as noted, changes to the content are additive. Changes made to the project content for FA11 to SP12 were the result of exploring the role of and the need to have standards when testing materials. Students were instructed to use the Form and Style for ASTM Standards (ASTM Blue Book) as a guide to create a standard for an impact test. The parameters of the impact test method are as follows: samples had to be able to withstand a fall of five (5) feet (approximately two (2) meters) at ten (10) repetitions with the release of contained liquid being a failure. The impact test was discontinued when the design artifact was changed.

In FA13, a module focused on sustainable concepts for materials selection was added to the course to provide more context to ecological impacts and to reinforce the concept of "real" design limitations in regards to materials[8]. The module drew from the developmental platform of life-cycle and systems thinking introduced in the freshman and sophomore years. The module project concentrated on analyzing and comparing the lifecycle phases of a wooden pencil versus a mechanical pencil to determine ecological impacts and to answer the question as to which was more of a sustainable product.

Other changes to the project in FA13 further reflect changes to the course content. With the Rapid Prototyping Laboratory coming online in the summer of 2013, the production of a conceptual prototype via 3D printing was added. The addition provided an opportunity for students to practice using CAD software and to become familiar with the capabilities of the laboratory.

An economic feasibility study was also added in FA13 to reinforce topics covered in the Engineering Management courses. Each team had to decide whether the prospective product would be a profitable investment for the company with the goal of maximizing shareholder wealth. The teams were instructed to calculate the net present value of the proposed container in order to determine economic feasibility. Based on the data, assumptions and calculations, the teams had to give recommendations as to either to continue funding the project to full production status or to halt the project in the conception stage. This addition to the integrative projected was not continued beyond FA13.

The greatest change to project content was coincident with the change in design artifact. Introduction of the shelf unit design artifact provided students with opportunity to apply mechanics concepts and analyses taught in class or in pre-requisite courses. Specifically, students were required to include:

- free body diagrams of the assembled and installed system
- free body diagrams of each individual component in the system
- description of the loading experienced by each member of the system and how that load would be modeled
- indication of limiting factor and how it is related to material properties
- analyses as required to determine limiting factor and how results impact material selection decision

Communication

The reputation of the materials project after the first iteration in FA11 grew from the students of that first cohort. Students that took the course advertised the challenging nature of the work and the unique format of the oral examination. Future students came into the course with knowledge rightly or wrongly expressed that only their best was expected and would be tolerated.

Changes with the interactions between the instructors and students were made during SP12. As a result of the unique nature of the presentation, a preliminary presentation was added to allow the students to practice. The preliminary presentation format was formative as opposed to the summative final presentation format. The preliminary presentation was replaced in later iterations (FA13-present) by project consultations. The project consultations allowed each instructor to sit with each group to review progress, to share insight, and to remind the teams of expectations. Writing center consultations were added to help teams better prepare the written report. An outcome of the writing center consultation that is largely under-appreciated by the students is the opportunity to explain the project to someone who is outside of engineering. These occasions with the writing center reveal the level of their ability to be clear, concise, and consistent.

A project debrief was added in SP13 to recognize the highlights, correct the common mistakes, to share experiences, and to link to real life work-place/team management scenarios. These sessions became a time of honest student reflection. These sessions were also the place where the students offered authentic critical assessments of themselves and their teams.

Student feedback on the Materials & Mechanics Course

This section provides student feedback related to the course in the form of Likert scale and written responses to prompts as well as some free responses.

Student Feedback via Likert Scale Responses

Likert scale responses are shown in table 2, below. The responses are related to three prompts:

- Compared to other classes taken, evaluate the challenge of this class
- This course has given me a better understanding of engineering

- Please rate how valuable the Group Projects and Presentations were in learning and mastering the course subject matter and content

Responses were gathered using standard end of semester course evaluation instruments administered by the university. The "value" question was not asked in FA11 while in FA13 the administration of the instrument was marred by clerical errors: lack of data for these cases is indicated by a "-" in the corresponding cell. Likert scale range and direction were both changed over the years of data collection; the responses below have been scaled to 1.0 and adjusted so that 1.0 would be the most desirable score.

Table 2: Student responses to prompts

	Challenge	**Understanding**	**Value**
FA11	0.87	0.90	-
SP12	0.80	0.91	0.87
FA12	0.92	0.90	0.85
SP13	0.91	0.84	0.79
FA13	-	0.88	-
SP14	0.93	0.90	0.85
FA14	0.95	0.89	0.84

In general, the perceived challenge of the overall course has increased over the four years of data collection while student perceptions of getting a better understanding of engineering and the value of the project show variation but no identifiable trend.

Student Written Feedback

Prompts provided by the standard instrument that allow for written free responses include:

- What did you like most about the course?
- What did you like least about the course?
- Any other comments?

Student responses to these prompts are shown below, organized by semester. Due to a clerical error, no written response data is available for FA13.

FA11

Liked most

- The class was design to stimulate real life environments.

Liked least

- The [mechanics and materials portions of the] courses are not very connected.

Comments

- The materials project could be better defined and executed.

SP12

Liked most

- My interests in engineering were broadened, and this class caused deep thinking.
- I liked having the presentation in the middle of the semester to prepare us for the final presentation. This really helped us understand what to expect and our group greatly improved because of it.
- I liked doing the final presentation, even though it was hard to take all the questions it was great practice for the real world
- I enjoyed doing the project even though it was very stressful.
- Personally, I was more interested in the materials portion of the class and enjoyed it very much. Even though the beverage container project was time consuming and a little daunting at times, I think I learned more from it than if we had only studied theory.
- I like the fact that the presentations put things in perspective for us. It took us all down a few pegs which was much needed and it was an eye opening experience.
- Being able to present and be graded like it was a real world presentation to individuals with a vast knowledge of the topic gave a wake up call to those who think they can just slide by. It also helped prepare for the real world.

Liked least

- I have never had such a demanding work load. I would not consider it a negative experience; I learned many things about myself and the material in the process.
- Not fully understanding all the connections of material information.

Comments

- I would like to say that my group and the related project was a very rewarding experience. Everyone in the group did their fair share of work and demonstrated a great group dynamic. This has been my first group experience that I do not have anything negative to comment on. Thank you.
- This course definitely broadened my interests in other areas of engineering and actually made my decision harder for what I wanted to pursue in graduate school.

FA12

Liked most

- Getting a taste of actual engineering related work
- I liked how the class project for the materials portion simulated industry and the type of reports/presentations many of us will be doing later in industry.
- I liked the material presented. The material was the first set of information in a course that truly gave me insight to what "real" engineers do.
- materials; the presentation (though I didn't do well on it) made me feel more at ease when presenting (at least for other presentations)

Liked least

- too much work
- presentations!!!!!!!
- I liked my grade the least about this course; however, I deserved it.

Comments

- You two really pushed me beyond my comfort zone and made for a rigorous, yet enjoyable course. I'm not as concerned with my grade as I am with the valuable knowledge I'm walking away with. Thank you for everything!
- I learned a lot in this class.
- Very good and challenging class
- Difficult but informative class
- Got me ready for the real world
- This class has changed my life

SP13

Liked most

- I thought that the project integrated a lot of the course concepts.
- The project was very helpful in putting all the material together.
- It really opened my eyes about the real world.
- I truly enjoyed the fact that we were expected to perform at the professional level and if we failed, we received critiques to better ourselves as engineers.

Liked least

- The project takes up a lot of time, but that was kind of expected.
- The beverage container project because of the level of complexity and working with members of group, however, the overall project was a valuable experience.
- The materials project
- The project was the most stressful project in my undergraduate career

SP14

Liked most

- I liked looking at materials and deciding what materials would be best suited for a certain design requirement. I also liked analyzing designs with mechanical analysis on certain designs/structures.
- The materials project is truly a marvel among all other engineering assignments received so far. I appreciated the depth and maturity level required for the assignment. If all classes were to have a similar structure, perhaps a better understanding of what an engineer actual is would be obtained.
- The shelf project and all of the real world engineering preparation that it taught me was by far my favorite part of the class.

Like least

- The course presentations and project. The presentations are a horrifying experience that has definitely deterred me from engineering. The negative environment it creates in the classroom does not help the students learn. Students can learn how to properly present through other methods besides the hellfire that is the project presentations

Comments

- I'm not going to lie, the presentation in particular really changed my perspective around 180 degrees. It felt somewhat similar to my pledging process -- it definitely got my heart beating and got me quite nervous until I actually started to present. After that, everything changed, and I felt I was able to convey what I knew to the best of my ability to a crowd generally unwilling to listen. It is an activity that all engineers should go through to re-evaluate why they are engineers in the first place.

FA14

Liked most

- The group project was helpful for gaining a better understanding of the principles involved in the problem solving approaches.

Liked least

- While the material presented in the course can be difficult to understand and the professors have very high expectations, I believe the professors were fair and helpful in challenging situations.

Comments

- This class was exactly what I needed to get myself back into why I was here at college. I got so sucked in to just doing the work for a grade I forgot to actually learn in the process. I was so helpful for me to see a glimpse into what the real world as an engineer would be like, from two well established teachers.

Instructor Comments Related to Student Feedback

Overall, many of the course comments address some aspect of the project with the presentation component receiving the most specific comments. The comments seem to indicate an appreciation for the application of high standards by the instructors from the standpoint of their perception that this approach better prepares them for the "real world". Themes that arise include a (somewhat begrudging at times) recognition that the students benefited from being challenged and their conclusion that the approach used in the course and project provided preparation for engineering life after college.

Although students expressed positive sentiments about the project in FA11, they also indicated that they needed more time to complete the assignment. Based on this input the project was changed to the full semester in SP12, although the focus remained on the materials portion of the course. The artifact change in SP14 and the associated inclusion of mechanics content to the project does not appear to significantly change the nature of student comments. Students continue to indicate that the project is difficult with some tacit or overt acknowledgement that the difficulty is an appropriate feature.

Observations

The development of ENGR 314 (and the integrative project in particular) to its current form represents a significant amount of effort and collaboration from both authors. The integrated approach described herein is not without its challenges: since the topics exceed the individual expertise of either contributor, neither is willing to teach the course in its current form individually so that the course is team taught. In general, team teaching approaches may lead to scheduling challenges and may also face administrative resistance. It is likely that such challenges will increase for cases in which teaching teams require expertise from more than one traditionally defined discipline and must cross departmental or college lines.

Conclusions

In conclusion, this paper described ENGR 314: Materials & Mechanics and the associated integrative semester long team project that combines traditional content of both materials science and mechanics of materials. In addition to the project, the course includes experiential learning in the form of hands-on laboratories for material characterization and mechanical analysis. ENGR 314: Materials & Mechanics provides students with a unique opportunity to recognize the topics of materials science and mechanics of materials as an interwoven collective. Although topics in each domain are presented from their traditional perspectives, they are integrated through the lens of design and systems thinking within the semester long project. The mostly positive student responses about the integrated nature of the project suggest that the majority of students perceive value not only with the course content but also with the project. It is recognized that integration of these topics may require more expertise than a traditionally trained instructor may have; this suggests that delivery of truly integrated content may require a teaching team. This is significant because there may be institutional barriers to creation of teaching teams, particularly if the teams cross disciplinary (and departmental) boundaries.

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