2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #38508

Introductory materials science: A project-based approach

Dr. Lessa Kay Grunenfelder, University of Southern California

Lessa Grunenfelder has a BS in astronautical engineering and a MS and PhD in materials science, all from the University of Southern California. In 2015 she joined the Mork Family Department of Chemical Engineering and Materials Science at USC as teaching faculty. She teaches both undergraduate and graduate courses on material properties, processing, selection, and design. She is passionate about sharing her love of materials science with students through curriculum that combines fundamental science and engineering application. Her research interest is in efficient manufacturing of high performance composites. She is an active member of the Society for the Advancement of Material and Process Engineers (SAMPE), serving on the Board of Directors of the Los Angeles Chapter as Student Chapter Liaison. She is currently the Division Chair of the Materials Division of ASEE.

Introductory materials science: A project-based approach

Abstract

There are several approaches to teaching introductory materials science, exemplified by the diversity of textbooks on the subject. Some favor a bottom-up approach, beginning with the fundamentals of atomic structure and bonding. Others opt for a top-down method, catching student interest by introducing impressive structures or dramatic material failures before diving deeper to interrogate the underlying science. Either instructional strategy, however, is enhanced when students can apply what they are learning and create meaningful real-world connections. One way to facilitate this is through project work. In this paper a semester long material and process selection project, consisting of multiple deliverables, is described. Detailed project assignments and grading rubrics as well as student perceptions of the project are presented.

Introduction

An introductory materials science course is a core component of undergraduate engineering programs at colleges and universities worldwide. When paired with a hands-on laboratory experience, the foundational concepts of materials science can be made tangible to students. In a lecture-only course, however, the relevance of course content to real-world application is often lost, and student understanding can suffer. This is because simple coverage of material by an instructor is not sufficient for student learning [1]. Research has shown that students are more motivated to learn when knowledge of course content can be connected to the solution to a practical problem [2]. To this end, it has been suggested that project-based learning (PBL) is a viable tool to support life-long learning and student understanding [3].

Prince and Felder [2] define PBL as "an assignment to carry out one or more tasks that lead to the production of a final product – a design, a model, a device, or a computer simulation. The culmination of the project is normally a written and/or oral report summarizing the procedure used to produce the product and presenting the outcome." PBL provides an authentic learning experience for students as completion of the project requires direct application of the content covered in class. Furthermore, as students undertake a project they encounter gaps in their knowledge, which motivates further inquiry and learning [2]. The structure of PBL helps to prepare students to enter the engineering workforce, in which a key job requirement is solving poorly defined and ill-structured problems [4].

An additional benefit of a project-based curriculum is the ability to emphasize dimensions of engineering design decisions that go beyond the technical functioning of a part or component. Research has shown that engineering curriculum in the United States prioritizes technical aspects of design problems over social dimensions, but success in the engineering workforce requires an understanding of the interplay between both facets [5]. In this context, "social" as a term encompasses environmental, ethical, economic, health, safety, political, and cultural factors [5]. The inherent duality of social and technical factors in the solution to a materials design problem is showcased beautifully in "the dual tetrahedron" proposed by Savage et al. (see Figure 1) [3]. The lower half of this figure will be familiar to the materials scientist. Core to the discipline is the interplay between structure, processing, and properties. Design projects have the benefit of emphasizing these relationships while at the same time bringing in the top tetrahedron in Figure 1 which highlights the economic, social, and environmental implications of material and process selection. The two tetrahedra converge at the “design solution” – the intended outcome of a design project.

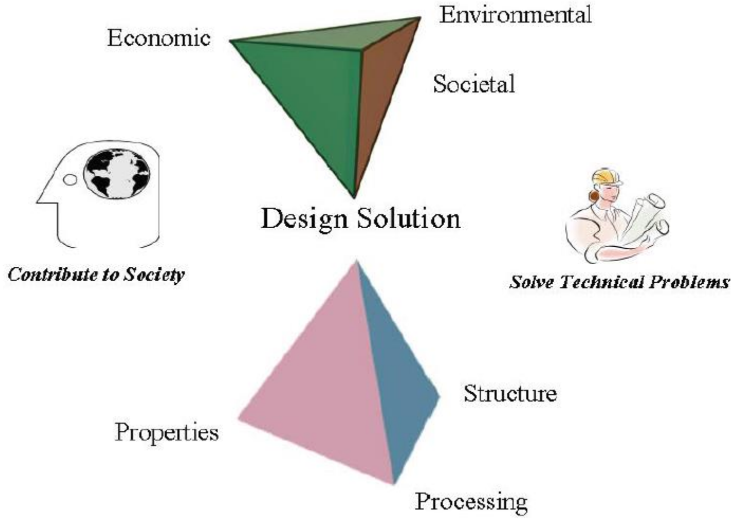


Figure 1. The “dual tetrahedron” – a visual representation of the connection between the technical and social aspects that must be considered in developing a design solution [3].

Project overview

To implement PBL in an introductory materials course at the University of Southern California (USC), students were tasked with a semester-long material and process selection redesign project to replace the failed component of a recalled product. The key to success with project-based learning is setting appropriate project parameters. For an introductory materials science course that covers topics including atomic structure and bonding, mechanical properties, strengthening mechanisms, failure, and manufacturing, a material and process selection project is an excellent fit. In his various textbooks (for example [6], [7]) Mike Ashby outlines a systematic approach to selection that ties in key concepts in materials science. The Ansys Granta EduPack software [8] is a material and process selection tool built around the Ashby approach and specifically designed for student use. The Ashby method, in combination with the EduPack software, provides a readymade template for a project-based course.

Material and process selection problems range from the very simple to the prohibitively complex. For a semester-long project, topics must be chosen close to the start of the semester. Tasking students with self-selecting a topic at the early stages of an introductory materials course is therefore not possible, as students do not have sufficient background to adequately assess the complexity of their proposed topic. To add to the difficulty of defining a project, engineered structures are not typically formed from a single material using a single processing method, but consist of assemblies of multiple parts made from dissimilar materials. Finally, an introductory materials course is not a full-blown design course. The scope of the project must be restricted to material and process selection for a single component with relatively fixed dimensions and loading requirements, such that students do not get sidetracked or overwhelmed by modifications to the general embodiment of a device. To overcome these issues the project described here was structured around the redesign of an existing product, with the scope is limited to the failed component. While the basic approach used for the project is not new, other materials educators may find the details of its implementation useful.

A common reason for redesign is product recalls. To give the project real-world connection and allow topic choices to be easily updated year after year, potential topics were selected by the instructor from the government recalls website [9]. The goal in choosing topics was to find recent recalls (from the past 6 months) to keep the project timely. With a bit of practice an instructor can quickly scan the recall list and identify failures that could be remedied by replacement of the failed component with a part composed of a more appropriate material or subjected to a more suitable process history. To provide sufficient variety, 6 topics were selected from the recall list each semester that the course was offered. A new set of topic choices each semester kept the project relevant and reduced concerns over potential plagiarism. A range of topic options allowed students autonomy in their choice and ownership over their project, while at the same time keeping assessment manageable.

The project was highly scaffolded by design. This served multiple purposes. First, completing and submitting regular deliverables kept students on track and allowed for regular instructor feedback on low-stakes assignments. Second, the organization of deliverables served as a model of expert thinking. The role of undergraduate education is not simply to teach facts, but to train experts. One skill experts possess is the ability to plan a task and develop an effective approach to solving a complex problem [1]. A project is simply a series of tasks that are undertaken to achieve an objective [3]. Each assignment description developed for the redesign project, therefore, presented an example of how an expert might approach a complex redesign problem providing students with a framework to refer to in the future. In this way the project was used to teach not just the materials science content central to the course, but also project management skills. The deliverables assigned for the redesign project are listed below, with full assignment descriptions and rubrics presented in Appendix A:

- Topic selection
- Annotated bibliography
- Draft introduction
- Plot formatting
- Translation
- Interviews
- Final written report
- One-slide summary and group presentation

While each project deliverable required self-directed learning by the students, the true PBL nature of the course came in at the translation stage of the project. In the translation, students were tasked with identifying the constraints and design objectives specific to their chosen topic. Determination of appropriate constraints and objectives was highly individualized and required not only application of course content but additional research and critical thinking. Each project topic required consideration of different property values and process requirements. In a one semester introductory course it was impossible to cover all attributes a student may need to address for any given topic. In completing a translation, therefore, students were required to grapple with ill-defined or conflicting requirements and practice the important skills of working with incomplete data and making educated and reasonable assumptions. “Science notes” describing a wide range of material properties are built in to the EduPack software. The software package, therefore, served as an interactive textbook and the primary reference for project information.

Redesign problems inherently involve social factors. Inspired by the work of Stephanie Claussen and colleagues [10], there was a desire to incorporate sociotechnical thinking into the course in an authentic way and foster sociotechnical habits of mind. This was accomplished via an interview assignment adapted from [10] in which students interviewed one engineer (either an engineering student not currently enrolled in the course, or a working professional) and one non-engineer, to obtain feedback on their proposed redesign solution. A class session exploring the idea of sociotechnical thinking and emphasizing its importance to the engineering profession helped to build student enthusiasm around the assignment. The interview deliverable was assigned over the Thanksgiving holiday when many students saw family and friends and had the time and opportunity to perform interviews.

In addition to grappling with sociotechnical factors, modern engineers must be effective communicators [11]. The final deliverable for the project was a written report, providing students with an opportunity to practice technical writing skills and receive feedback on their writing. For their redesign project students were constrained to keep the same overall design for the recalled product and simply swap out the failed part with a replacement made using a different material and/or processing method. After selecting within these boundaries, however, students were free to discuss in their report if they thought a design change would be a more appropriate solution to prevent future failures.

While the redesign project was an individual effort, PBL has been shown to be more effective when carried out in teams [3]. To add a collaborative component to the experience the course culminated in a series of group presentations. In addition to their final report, each student created a one-slide summary of their redesign solution, highlighting their key constraints and design objectives, and showcasing their final material and process choices. Students who worked independently on the same topic were put into groups to discuss their approach to the project and their final solution. Each group then created a presentation synthesizing their efforts and describing how emphasis on different design factors (i.e. seeking a low cost vs prioritizing sustainable choices) led to different solutions to the same problem. This culminating experience provided students a chance to discuss the project, share their results, and see first-hand how open-ended material and process selection can be. During the final exam period scheduled for the course each group gave a short presentation to the class. This ensured that all students were exposed to the six different project topics and were given the chance to hear about the work their peers had been doing throughout the semester.

Results

Assessing an instructional technique is complex. The present work is meant to primarily serve as a description of the approach to enable other educators to implement a similar project-based model. There are, however, a few metrics by which the impact of the redesign project can be examined.

In end of semester learning experience evaluations at USC, students are asked to rate several aspects of their courses on a scale of 0-4. Two evaluation categories particularly relevant to the shift in instructional design from a traditional exam-based model to a project-based model are "assessment practice" and "course impact." The course in which the project was implemented (MASC 310: Materials Behavior and Processing) is taught every year. Data from learning experience evaluations for four recent offerings of the course using an exam-based model (Fall 2018 and Fall 2019, 2 sections each) were compared to six offerings of the PBL version (Fall 2020 – online and Fall 2021 – in person, three sections each). All ten sections of the course were taught by the author.

Two specific attributes of "assessment practice" and three attributes of "course impact" were compared using a one tailed t-test for 2 independent means, with a significance level of 0.05. The mean student ratings across all exam-based sections of the course were compared to the mean ratings from the project-based sections. Results are presented in Table 1 below. Note that the lecture content across all course offerings was essential the same, it was the method of assessment that differed.

Table 1. Statistical analysis of student ratings for assessment practices and course impact comparing a lecture-based version of the course to a PBL version

Category	Title	Question	t-value	p-value
Assessment Practices	**Relevance of assessment**	**The assessments/assignments reflected what was covered in the course.**	**4.62**	**0.000853**
	Grading fairness	The grades I have received thus far reflect the QUALITY of my performance in the course.	3.13	0.00703
Course Impact	Learning	I learned perspectives, principles, or practices from this course that I expect to apply to new situations.	3.55	0.003762
	Critical Thinking	**This course challenged me to think critically and communicate clearly about the subject.**	**5.83**	**0.000196**
	Applicability	This course provided me with information that may be directly applicable to my career or academic goals.	3.23	0.006011

While all increases in student ratings for the PBL version of the course as compared to the exam-based instructional model were found to be statistically significant, the largest increases were noted in the questions elucidating perceived relevance of assessment to content covered in the course, and impacts on critical thinking and communication (bolded rows in Table 1). Graphical data showing each course section individually is presented in Figure 2 for visual comparison.

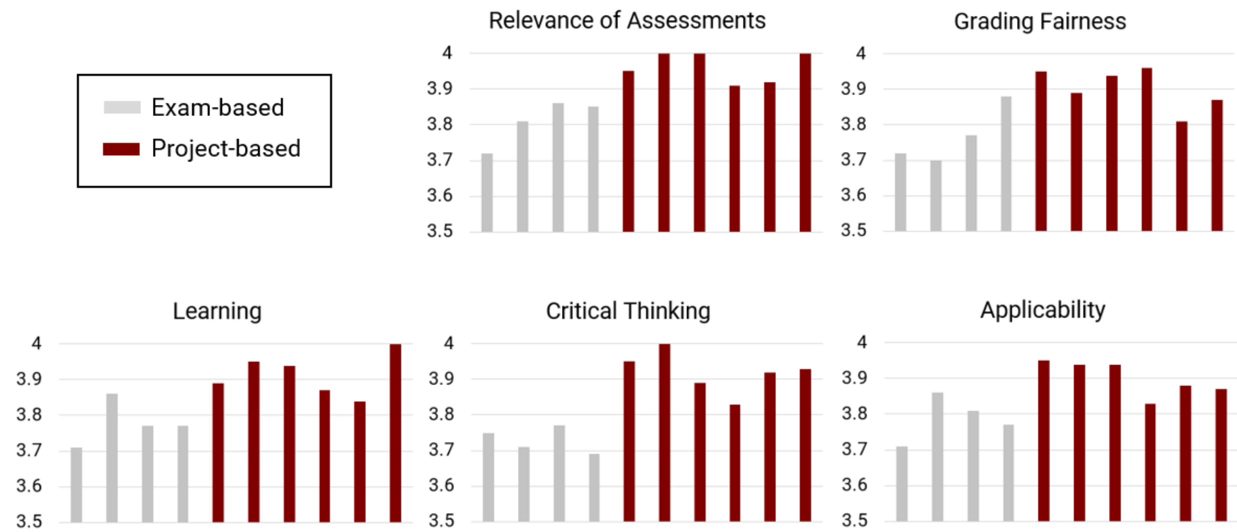


Figure 2. Student learning experience evaluation data from exam-based sections of the course (gray) and project-based offerings (dark red).

In addition to student ratings of various course attributes, insight can be gained from open-ended comments on end of year evaluations. All comments from the six PBL offerings of the course that specifically addressed the project were compiled and are presented in Appendix B. Most comments were favorable (14) though negative comments about the project-based model were also made (3). General themes from favorable comments included:

- student appreciation for intermediate project deliverables as a means to receive feedback and remain on track
- a course structure that facilitated real-world connections and provided practical knowledge students perceived as useful to their future coursework or career
- a reduction in the stress and feelings of overwhelm that can accompany exam-based instructional models

No instructional approach, however, will be a favorite for all students. Negative comments expressed a desire for more traditional exam-based assessment.

As all ten sections of MASC 310 examined here were taught by the same instructor and covered the same general content, a final comparison that can be made to evaluate student performance is grade distribution. Figure 3 shows the fraction of students enrolled in MASC 310 each year (two sections each of exam-based in 2018 and 2019, and three sections each of problem-based in 2020 and 2021) who earned grades between and A-C, passed the class on a pass/fail option (P), failed the class (F), or withdrew (W).

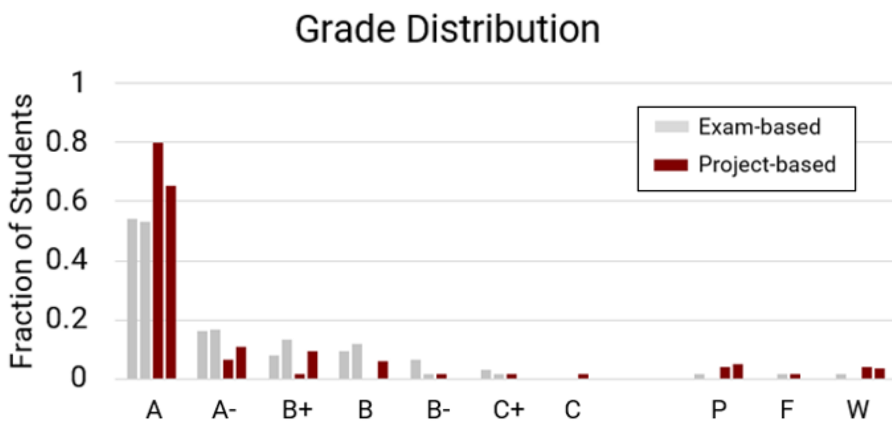


Figure 3. Grade distribution for four years of MASC 310 classes. Each gray bar represents an average over two course sections with an exam-based approach and each red bar an average over three sections of a project-based course.

This data cannot be used for direct comparison, as the grade breakdown was different in the traditional exam-based version of the course as compared to the project-based version. Both courses, however, included in-class problem solving activities requiring conceptual understanding. The second year of the project-based course (final set of red bars in Figure 3) also included weekly homework assignments on course content. The main takeaway of the grade data is a clear increase in the fraction of students who earned an A in the course.

Discussion

The grade distribution data in Figure 3 shows an increase in the fraction of students to earn an A in the course. This does not necessarily correlate with a higher level of student learning. It is not uncommon with PBL to base grades on project performance and eliminate exams. With this structure, however, questions can arise as to how best assess student learning and assign grades [3]. It is a general concern with PBL that students may exit a course with a stronger understanding of how to apply their knowledge in engineering practice, but a potentially less rigorous understanding of fundamentals [11]. Project-based learning has, however, been shown to be one approach to level the playing field and better serve students who might not succeed in a traditional exam-based environment [2], [12]. There is no undergraduate materials science major at USC, so for most students MASC 310 is the only materials course taken. For this reason, data is not available on retention of knowledge or performance in subsequent materials classes.

While the assessment metrics here were limited, previous work has shown tangible benefits to the incorporation of PBL in engineering, and specifically materials, education. With a shift to a greater fraction of project-based coursework in the materials department at Cal Poly an increase in the number of students transferring into materials engineering was reported, along with increased retention of students between the first and second years [3]. Other studies have shown similar benefits for retention in engineering with a PBL curriculum [12].

A criticism of many engineering curriculums, and an issue at the core of recent revisions to accreditation standards, is that students are not provided with sufficient design experience [11].

Too often the curriculum is bookended by a first-year design experience and a senior design project, with a remainder of technical coursework. There are opportunities, however, to introduce design across the curriculum. An introductory materials course is a common requirement for a range of engineering majors, and is typically taken in the sophomore or junior year. A project like the one described here could therefore be adopted at a range of institutions. Past studies have demonstrated the benefits of junior-level project work in preparing engineering students for challenging capstone design courses [13]. Using a materials course as a vehicle to teach the Ashby method and EduPack software to students prior to senior design is particularly effective. Many students who took the MASC 310 course went on to use EduPack as a tool in their senior design work.

Conclusion

Two years of successful implementation of the redesign project described here, for both online and in-person courses, showcases the feasibility of a project-based approach for introductory materials science. It is important to note, however, that while the project drove student learning to an extent, the core content presented in previous exam-based versions of the course was largely unchanged. The nature of the course might be better described as what Mills and Treagust term “project-assisted learning” as opposed to true project-based learning [11]. This is the case because materials science as a discipline has a hierarchical structure. Without knowledge of the fundamentals, more complex topics cannot be understood [11]. Lecture time in MASC 310 was used for direct instruction and active learning experiences to ensure all students had a strong foundation. The redesign project then allowed students to explore more specialized topics independently. With this model, all students learned, for example, about the atomic level structure of materials and basic mechanical properties, while specific project topics lead some students to explore optical properties in detail, while others focused on thermal properties, the influence of specific deteriorative environments, etc.

Incorporating sociotechnical thinking further contextualized the real-world nature of the project, helping to emphasize to students that design decisions have broad consequences and reinforce the need to consider both social and technical factors in engineering practice. The introduction of a design project in the sophomore or junior year, and teaching of a selection tool like EduPack, additionally helped to prepare students for their capstone design experiences. These outcomes were achieved while still covering the basic materials science content common to an introductory course. Student perceptions of the project were overwhelmingly favorable, and responses to course evaluation questions on assessment and course impact indicate that a project-based approach has meaningful benefits for student learning. Finally, while the redesign project replaced exams in the MASC 310 course, a project like the one described here could certainly be assigned in addition to, rather than in lieu of, traditional exams, to meet the learning outcomes of a course or instructor.

References

[1] *How People Learn*. Washington, D.C.: National Academies Press, 2000. doi: 10.17226/9853.

[2] M. J. Prince and R. M. Felder, “Inductive teaching and learning methods: Definitions, comparisons, and research bases,” *Journal of Engineering Education*, vol. 95, no. 2, pp. 123–138, 2006, doi: 10.1002/j.2168-9830.2006.tb00884.x.

[3] R. N. Savage, K. C. Chen, and L. Vanasupa, “Integrating Project-based Learning throughout the Undergraduate Engineering Curriculum,” *Journal of STEM Education*, vol. 8, no. 3 & 4, 2007.

[4] R. M. Marra, C. Plumb, and D. J. Hacker, “Developing Metacognitive Skills in PBL Undergraduate Engineering Introduction and Background,” in *ASEE Annual Conference*, 2018.

[5] K. Johnson, S. Claussen, J. A. Leydens, J. Blacklock, J. Y. Tsai, and N. Plata, “The Development of Sociotechnical Thinking in Engineering Undergraduates,” in *ASEE Annual Conference*, 2022. [Online]. Available: www.slayte.com

[6] M. Ashby, *Materials Selection in Mechanical Design*. Elsevier Science, 2016.

[7] M. Ashby, H. Shercliff, and D. Cebon, *Materials: Engineering, Science, Processing and Design*, 4th ed. Elsevier, 2019.

[8] https://www.ansys.com/products/materials/granta-edupack, “Ansys Granta EduPack.”

[9] “https://www.cpsc.gov/Recalls.”

[10] S. A. Claussen, J. Y. Tsai, A. M. Boll, J. Blacklock, and K. Johnson, “Pain and Gain: Barriers and Opportunities for Integrating Sociotechnical Thinking into Diverse Engineering Courses,” in *ASEE Annual Conference*, 2019.

[11] J. E. Mills and D. F. Treagust, “Engineering education-is problem-based or project-based learning the answer?,” *Australian Journal of Engineering Education*, 2003, [Online]. Available: http://www.aaee.com.au/journal/2003/mills_treagust03.pdf

[12] H. A. Hadim and S. K. Esche, “Enhancing the engineering curriculum through project-based learning,” in *32nd ASEE/IEEE Frontiers in Education Conference*, 2002. doi: 10.1109/fie.2002.1158200.

[13] S. Kaul and W. Stone, “Learning Outcomes of a Junior-Level Project-Based Learning (PBL) Course: Preparation for Capstone,” in *ASEE Annual Conference*, 2015.

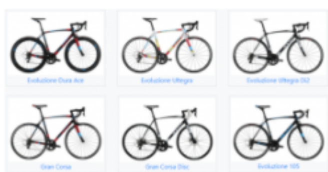
Appendix A: Deliverable descriptions and grading rubrics

Project Choices

Material and Process Selection Project: Topic List

For your semester you will undertake material and process selection to replace a component in a recalled product. You are not redesigning the entire product, only the failed component. Six project options are listed below with links to the recall notice. If you would like to propose your own topic, please discuss with me first.

Glass carafe	JULY 8, 2021  **LoHi Tech Recalls SOWTECH Espresso Machines Due to Burn Hazard (Recall Alert)** The glass carafe can break while in use, posing a burn hazard to consumers. **Remedy:** Consumers should immediately stop using the recalled espresso machines and contact LoHi Tech to receive a free replacement metal carafe. LoHi Tech is contacting all purchasers directly. **Units:** About 24,900
Plastic dishes	MAY 19, 2021  **IKEA Recalls Bowls, Plates, and Mugs Due to Burn Hazard** The bowls, plates, and mugs can become brittle and break, causing hot food or liquid to leak out, posing a burn hazard. **Remedy:** Consumers should immediately stop using the recalled bowls, plates, and mugs and return them to any IKEA store for a full refund. **Units:** About 148,000 (In addition, about 11,400 were sold in Canada)
Folding chair	MAY 5, 2021  **TJX Recalls Outdoor Wooden Folding Chairs Due to Fall and Injury Hazards; Sold at T.J. Maxx, Marshalls, HomeGoods and Sierra** The chairs can break, posing fall and injury hazards to the user. **Remedy:** Consumers should immediately stop using the recalled chairs and contact TJX for instructions on how to participate in the recall and receive a full refund. Alternatively, consumers can return the recalled chairs to any T.J. Maxx, Marshalls, or HomeGoods store for a full refund. **Units:** About 82,500

Towel bar	MAY 5, 2021  **Signature Hardware Recalls Towel Grab Bars Due to Fall and Injury Hazards** The product can break, if the towel bar is used to provide bodily support, posing fall and injury hazards. **Remedy:** Consumers should immediately stop using the recalled product and contact Signature Hardware for a full refund or a free replacement grab bar. **Units:** About 330 (In addition, about 5 were sold in Canada)
Drive belt	MARCH 25, 2021  **Polaris Recalls Ranger Recreational Off-Highway Vehicles and ProXD, Gravely and Bobcat Utility Vehicles Due to Fire Hazard (Recall Alert)** The drive belt can break during operation and damage the inner clutch cover assembly and fuel line, which can result in a fuel leak, posing a fire hazard. **Remedy:** Consumers should immediately stop using the recalled vehicles and contact a Polaris, Ariens, or Bobcat dealer to schedule a free inspection and repair, if needed. Polaris, Ariens, and Bobcat are notifying all dealers and contacting registered owners directly. **Units:** About 41,500 (In addition, 1,475 units were sold in Canada) (some of the Model Year 2020-2021 RANGER 1000 and RANGER CREW 1000 and Model Year 2020 ProXD 2000G and ProXD 4000G units were previously recalled and some of the Model Year 2020 RANGER 1000 units were previously recalled for different hazards).
Fork steerer tube	MARCH 3, 2021  **Haro Bicycles Recalls Masi Evoluzione and Gran Corsa Bicycles Due to Fall Hazard and Risk of Injury** The bicycle's fork steerer tube can break, causing the rider to lose control, fall and suffer injuries. **Remedy:** Consumers should immediately stop using the recalled bicycles and contact their local Haro Bicycles dealer for a free inspection, and repair or replacement of the fork and compression plug. **Units:** About 510

Name:

Material and Process Selection Project: Deliverable 1

Complete this worksheet and save as a pdf. Submit via the “deliverable 1” assignment link in Blackboard.

Major:

Consult the project topic list posted on Blackboard, then complete the following

First Choice (check the box next to the product you would most like to focus on)

☐ Glass carafe ☐ Plastic dishes ☐ Folding chair ☐ Towel bar ☐ Drive belt ☐ Fork steerer tube

State why the part/product interests you. Brainstorm and list 4-6 properties critical to consider in selecting a replacement material and manufacturing method for the part/product. Think about design loads, service environment, economic and environmental factors, and details to appeal to customers.

Second Choice (check the box next to the product you have the second most interest in)

☐ Glass carafe ☐ Plastic dishes ☐ Folding chair ☐ Towel bar ☐ Drive belt ☐ Fork steerer tube

Repeat the above for your second-choice topic

Material and Process Selection Project: Deliverable 2

Create an annotated bibliography in word processing software and save as a pdf. Submit your pdf file via the “deliverable 2” assignment link in Blackboard.

What I want you to do:

Research the product or component you are redesigning, as well as external factors that will be important for your material and process selection. Create a list with a minimum of 6 sources, the first of which should be the recall notice itself. For every source on your list write a short paragraph to describe what information you found in the reference, and how it is applicable to the project.

Why I want you to do it:

A good starting point for any project or report is background research. Before you can complete an accurate translation for your redesign problem you need a solid understanding of what your chosen product or component is and how it functions. You also need access to information to help you determine numerical values for constraints. Your final redesign report is expected to be well researched and appropriately referenced. This research and referencing component starts now.

How I want you to do it:

In a word document, make a numbered list of references. Use ASME format for citations. Go beyond just a google search - Use tools like Google Scholar and the USC Library to find academic references. At least two of your references must be articles, book chapters, or other credible academic sources. Denote academic references in your submission using red text. See the example on the following pages.

Grading Rubric

Component	Points possible
At least 6 total references	3
At least 2 academic references (denote with red text)	1
References in ASME format	1
Paragraph of text accompanying each reference that provides details on the content of the reference and its relevance to the project	5

Points will be deducted for: vague or missing annotations, broken links, improper citation format, significant grammatical errors.

Material and Process Selection Project: Deliverable 3

Write an introduction to your redesign report topic. Include an image, a statement of function, and the structural element you will use to model the failed component. Save your intro as a pdf and upload to the submission link on Blackboard.

What I want you to do:

Write a short introduction to your redesign project topic that includes an image of the product and/or failed part, a statement of function, and (if possible) specifies what structural element you will be using to model the failed component. In your introduction state the motivation for a redesign and discuss key properties and attributes that will be considered for material and process selection.

Why I want you to do it:

By the end of the semester, you will complete a full redesign report, culminating in selection of a specific material and manufacturing method to replace a failed component. To keep you on target and provide opportunities for intermediate feedback, aspects of the report will be submitted throughout the semester. The introduction you write for this assignment will be revised based on instructor feedback and incorporated into your final report.

How I want you to do it:

In a word document, write a brief introduction in paragraph format. Cite any sources (for information or images) using [ASME format] - which includes in-text citations that appear in numerical order in square brackets. All images require a descriptive figure caption. Your introduction should be no more than one page, single spaced, through references can appear on a second page. See example on the following pages.

Grading Rubric

Component	Points possible
Image of product or part	1
Statement of function with (if possible) specification of structural element that will be used to model the part	2
Text: Introduce the failed product/part (2 pts) and detail the need for a redesign – focusing on material and process selection and target market (2 pts)	4
References: All sources cited (1 pt), numbered reference list (1 pt), References in ASME format (1 pt)	3

Material and Process Selection Project: Deliverable 4

For this assignment you will create two plots as practice for the plotting, chart manipulation, and data presentation you will do in your semester selection project.

What I want you to do:

Make the two plots described on the following page using **Level 3** of the GRANTA EduPack software. Format each plot as described and copy into a word document. For each material index plotted, include a table with a ranked list of top materials and add a descriptive figure and table captions.

Why I want you to do it:

Your final project report will contain several plots produced using the GRANTA EduPack software. The purpose of this assignment is to practice making and professionally formatting plots to ensure that the charts submitted in your final project document are clear and useful visuals. While each student will have different plots in their final report, specific to their selection project, for this deliverable all students will produce the same two plots. This assignment will also introduce the Level 3 database and use of appropriate figure and table captions.

How I want you to do it:

Follow the instructions on the next page. Paste each plot into a word document to add captions. Include a ranked table of top materials with each plot. Save your file as a pdf and upload to the deliverable 4 submission link on Blackboard.

Grading Rubric

Component	Points possible
Proper axes and selection lines plotted	1
Appropriate short list of 5 materials selected based on BOTH index values	0.5
Proper material subset, family envelopes, specific material labels for top 5 options, relevant envelope label(s)	1
Clear and legible axis numbers and labels	0.5
Numbered figure captions describing each plot	1
Ranked table of materials for each index, with table caption(s)	1

Material and Process Selection Project: Deliverable 5

Translate the requirements of your redesign to a prescription of function, constraints, objectives, and free variables. Save as a pdf file and submit via the "deliverable 5" assignment link in Blackboard. See example on the following pages.

What I want you to do:

The next step in the redesign process is to translate the requirements of your design into specific constraints and objectives for both material and process selection. Provide a brief written introduction describing the design objectives. Include an appendix showing any calculations made and justifying constraint values. Include citations to all sources.

Why I want you to do it:

Translation is the critical step in selection. A thorough translation will ensure your redesign report comes together smoothly. This assignment will give you the chance to examine the detailed requirements for your part and explore the property values available in the software in more detail.

How I want you to do it:

A table is the best way to present the details of your translation. To ensure all students complete projects of comparable difficulty and quality, the following must be included in your translation:

- Statement of function, including, if possible, the structural element used to model the part (can be copied from your introduction - check feedback first for any necessary edits)
- A minimum of 8 quantitative constraints ("quantitative" in this case includes durability ratings and any other values that can be screened for in the software). **List property names as they appear in Level 3 of the software** (for example, endurance limit should be listed as "fatigue strength at 10^7 cycles"). Include if each value is a minimum or maximum limit, or range, and include units (where applicable) that match the metric units in the software.
- A minimum of 2 material indices to rank materials based on design objectives. Do not derive indices, select them from the "Learn" tab in the software. Be sure to select the proper indices based on your structural element and free variable(s) or other design attributes
- A list of free variables (include choice of material, choice of process, and any geometric free variables).

Preceding your translation table include a written overview of design objectives. Include a detailed appendix at the end of your document showing any calculations and justifying constraint values.

Grading Rubric

Component	Points possible
Written overview of design objectives	1
Statement of function including, where appropriate, how the part will be modeled	1
Minimum of 8 constraints, properly named, with values and units (where appropriate)	4
Minimum of 2 material indices matching design specifications	2
Well referenced appendix detailing constraint determination	5
Reference list, in ASME format. Citations (in numerical order) in text.	2

Material and Process Selection Project : Deliverable 6

Conduct interviews with an engineer and a non-engineer. Submit a transcript of each interview, along with a short reflection, using the submission link on Blackboard. Incorporate insight from your interviews into your final project report.

What I want you to do:

Select one working engineer or another engineering student (not currently taking MASC 310) and one non-engineer. Conduct two separate interviews where you discuss your material and process selection project with each interviewee.

Why I want you to do it:

As discussed during our class session on sociotechnical thinking, the profession of engineering does not prioritize technical work over all else. Working engineers must also consider the social (environmental, ethical, economic, health, safety, political, cultural) aspects of any project. When working on a project individually, it is easy to adapt a narrow focus. Discussing your project with others, including people from outside your field, will help to reveal any gaps in your thinking.

How I want you to do it:

Select one engineer and one non-engineer to interview. Conduct your interviews separately. Begin by describing your selection project:

- Introduce the product and how it failed
- Describe your proposed solution (replacement material and processing method)

Ask the questions in the provided word document and make note of responses (this can be done in person/on Zoom or over email by sending a summary of your project along with the questions to your interviewee). Fill out the reflection questions after both interviews are complete. Save your completed word document as a pdf and upload using the link on Blackboard (**due with the final report on the last day of classes – Dec 3rd at 11:59 pm**)

Note: While the details of your interviews should not be included in your final project report, it is expected that your report address sociotechnical aspects of design and incorporate insight gained from this assignment.

Grading will be based on completing both interviews and providing a thoughtful reflection.

Final Report	**50 pts**
Problem Statement and background	
Introduction to the product, including a photograph or schematic	/2
Discussion of the need for a redesign (what failed and how/why?)	/2
Summary of design objectives	/1
Selection criteria (translation)	
Statement of function (including structural element used to model the part, if applicable)	/1
A minimum of 8 quantitative constraints	/2
A minimum of 2 material indices (matching design objectives)	/1
List of free variables (including choice of material, choice of process, and geometric variables)	/1
Screening and ranking	
Written description of selection of material and process, incorporating charts	/8
Data table of diverse top material choices (minimum 5 unique materials), ranked based on indices	/3
Documentation	
Discussion of top material and process options and benefits/drawbacks to each, supported by data	/3
Final choice of specific material (from Level 3) and primary shaping process	/2
Compatible material and process(es) chosen; all process steps (heat treatments, etc.) discussed	/2
Description of primary shaping process, including a photograph or schematic	/3
Concluding remarks: Discussion of if these choices make sense/have been used in similar applications in the past. Evidence of validity of choices presented. Sociotechnical aspects addressed.	/3
Data presentation: Figures and tables	
A minimum of 3 charts produced in the GRANTA EduPack software (bubble or bar charts)	/3
Proper plotting and use of material indices	/2
Additional charts and data provided to support material and process selection	/2
Figures (images, charts, etc.) numbered and presented with detailed figure captions	/1
Tables numbered separately and presented with table captions	/1
References	
Citations appear in square brackets, in numerical order in the text	/2
All images taken from outside sources cited in figure captions	/1
Numerical bibliography at the end of the report, in ASME format, including academic sources	/2
Appendix	
Appendix showing any calculations and justifying constraint values	/2
One-Slide Summary	**5 pts**
Redesign project topic	/0.5
Final material and process choices	/2
Statement of the most interesting and/or surprising thing you discovered	/1
Format to be visually appealing (use images and limit text as much as possible)	/1
On-slide citation for any images taken from outside sources	/0.5
Late deductions: 5% deduction immediately following due date, additional 10% every 12 hrs thereafter	

Appendix B: Open-ended student evaluation comments

The project deliverables kept me up to date with the course so I wasn't cramming at the end of the semester.	The final project was really cool. The deliverables were helpful	The deliverables really helped with the final project
The redesign project was a rewarding way to apply what was learned in lecture. The project was also presented in such a way that it never felt overwhelming -- deliverable objectives kept us on track and ensured that we were getting timely feedback and making progress. This was a very concrete project which I feel has equipped me with skills necessary to be a successful engineer.	the homeworks and projects were directly related to what we learned in class and they helped me solidify some of those concepts...I know I will use this content for design projects in the future and learned a ton from this class.	Class was always interesting and engaging, and outside homework and projects always felt relevant to the material and helped learning without being overwhelming.
This is a great comprehensive introduction to materials and processing. I got very interested in materials science and learned enough to continue exploring in this field. The course is very well-structured and the project gives great insight to students who want to go into the materials industry.	Every aspect of this course was tailored perfectly to a modern day learning experience. I really enjoy the in class activities and I think the final project has brought together everything I have learned this semester really nicely	I really liked how the class was structured overall. I liked the fact that there was a project instead of an exam because I applied the things I learned to a real-life redesign project.
I think the best part of this class was how practical everything was. I really loved how each topic was incorporated into the redesign project, and that the project was semester-long so we could truly take the time to apply what we were learning to a real-world issue.	Every session was informative and I learned new materials every week. There were a lot of assignments but they prepared me for the final project and evaluated my understanding of the topics discussed in class.	Projects had clear grading rubrics. Projects used skills and topics taught in class but applied them in a practical and memorable way.
The most valuable aspect was that we weren't stressed out about tests and were able to learn the material instead. The project at the end really tied everything together.	The fact that it was project rather than exam-based allowed us to apply what we were learning much more efficiently.	
I think that the least valuable aspect of the class was the course project. It was only related to a lot of what we covered in the beginning of the course, and then the material strayed away a bit.	As a matter of personal preference, I would rather have a more conventional course in terms of assessment of understanding of the content	Class was very project-intensive. Would have preferred more testing.

*All spelling/formatting is the students own