AC 2011-2497: INTEGRATING EMERGING TECHNOLOGIES WITH ENGINEERING DESIGN COURSES

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Integrating emerging technologies with engineering design courses

Abstract

An engineering design course is proposed which combines the teaching of design theory with emerging technologies in engineering disciplines and application to a design project. The term *emerging technologies* is presented to imply a broad application of the ideas presented in this paper, giving flexibility to the design course implementation in specific curriculums. It is proposed that the outlined design course has the potential to increase student's engagement in the design process because of the wide scope and opportunities for progression that emerging technologies inherently possess. Additionally, this design course presents an opportunity for students to explore the possibilities of design problems through the application of technologies which are not well developed, naturally propelling the growth in the particular engineering field. Based on a typical American University semester format, the instruction is divided into two equal segments; the first half focuses on details regarding the emerging technology and design theory, while the second half utilizes teams of three to five students working as a group to apply the skills gained from the first half of the semester and propose solutions to a design problem. A discussion-based classroom setting is used to create a "constructivist" environment, through which student-centered learning is fostered.

The design course outlined here is aimed at junior-level engineering students and is interdisciplinary in nature by offering the course as a general engineering elective. An aspect of consideration is the apparent value of an engineering design course offered prior to the capstone design project currently found in most engineering curriculums in the U.S. and typically encountered during the senior year of study. It is argued that the course presented in this paper would help to fill this gap prevalent in many engineering curriculums between the freshman and senior years of instruction and better prepare students for rigorous engineering design encountered in industry and other post-graduation settings. To illustrate particular aspects of the design course, the present work will focus on a specific emerging engineering technology, namely composite materials. It is noted that as progression in various fields and technologies is made, the scope of the design course is structured to be adapted accordingly.

1. Introduction

Current undergraduate engineering curriculums implemented in American universities generally contain an introductory design course during the freshman year of study along with a capstone design project during the senior year [e.g. 1-4]. This approach to the curriculum neglects significant engineering design experience during the sophomore and junior years of study. Students pursuing STEM degrees in general (and engineering degrees specifically) are found to already have a firm foundation in the "hard" sciences needed for engineering upon entering into the University setting [5], but can often graduate unprepared for the design aspect of engineering necessary in many post-graduation settings [6]. It is therefore important to reevaluate how engineering curriculums prepare students for the "art of design" [7]. Researchers in the engineering education field have previously addressed this issue and proposed a more integrated approach to teaching design skills to young engineers throughout the undergraduate curriculum [e.g. 8]. The following attempts to address this same issue of design instruction in undergraduate engineering curriculums and outlines a proposed design course which can be best described as a "guided design experience."

The primary purpose of the design course presented in this paper is to supplement the current design instruction of undergraduate engineering students and fill the design gap prevalent during the middle years of undergraduate engineering study. By primarily focusing the proposed design course towards junior-year level engineering students, an attempt is made to address the concerns of a curriculum modeled according to the situation described above (where design is taught primarily near the beginning and the end of the curriculum and not throughout). As engineers are often required to engage in design projects after graduation, a better preparation for this setting should be considered in the curricular approach.

Two important issues to consider are the retention and interest of students in the engineering program, which are directly related to the curriculum's focus and outcomes towards preparing each enrolled student for a career beyond graduation [9-10]. By proposing a new design course which combines the instruction of design theory with principles of emerging technologies applied towards a relevant design problem, it is argued that students' perceived significance of the topics and relevance towards career applications are enhanced. As a result of completing this course, the students will practice the design process, be able to explain and discuss the emerging technology, be able to apply basic governing principles of the emerging technology to a design project, and be better prepared for investigation within a team towards rigorous design challenges. The following report will go into more detail regarding the proposed course and will outline specific course learning goals and objectives, sample course discussion topics, grading policies, course texts, the teaching format and instructional methods, and assessment measures of the course learning goals.

2. Scope and Assumptions

The proposed design course is outlined according to a typical American University semester-based (14 weeks) format and aimed to attract students across engineering disciplines. Students are not expected to have any previous knowledge of the emerging technology; rather the course will serve as a platform to expose undergraduate students to new engineering topics and ongoing research within the specific university's engineering department. It is implied throughout this document that the instructor of the design course is directly involved in ongoing engineering-related research around which the individual course is tailored. In order to best exemplify particular aspects of the design course the present work will focus on a specific emerging engineering technology, namely composite materials. A few examples of other potential emerging technologies which could be incorporated into the current proposed course include nanorobotics, fuel cells, thermal energy storage, biotechnology, and piezoelectric energy harvesting. As various engineering fields and technologies progress, the details of the design course are structured to be adapted accordingly.

The ideas and materials presented in this report are relevant to departmental administrators, potential instructors, and faculty involved with planning and directing engineering course curriculums. While the course proposed in this document is based on many references, three resources form the primary core of the course's development: engineering education principles presented by Dr. Goff in ENGE 5024: Design in Engineering Education and Practice at Virginia Tech [11], course development resources developed at Virginia Tech by the Faculty Development Institute (FDI) [12], and a book on design theory authored by Ullman [13]. By synthesizing several of the ideas and methods presented in the previous three resources along with a selection of supplemental literature, a comprehensive engineering design course structure has been developed and is outlined in the sections which follow.

3. Course Context

Many factors relating to the learning environment and a student's past experience will affect how well the instruction and course topics are perceived by the student [11, 12]. It is important to first consider the background and knowledge that students may potentially bring into the course. Since the current course is aimed at junior-year level students in a typical four-year engineering program, some assumptions must be made regarding the students preparedness (which may differ across particular University programs). In general, the course aims to be relatively "stand-alone" within the junior-year course curriculum, where the material covered is not intended to build on specific previous courses. Table 1 presents a sample of an initial analysis involving the main aspects of the course and how they will be approached from an instructional standpoint.

After covering the basic principles of the emerging technology and design theory through examples and discussion, these topics will be applied through a design project which will ask the students to exploit the benefits of composite materials. It should be noted here that the main objective of the design course (and consequently the design project) is not for the students to intensively research the chosen emerging technology, but rather to explore the conceptual domain where the emerging technology could be beneficial. Students will work in teams to identify a particular design need or improve upon an existing design and apply the design process along with an aspect of composite materials to solve the design problem. Further details regarding the design project assignment are given below in Section 4.

Table 1. Examples of course context factors

Main Topics	Sub-Topics	Readiness To Learn	Degree of Difficulty	Instructional Strategies
Theory of Design	Six stages of design	Yes	Basic	In-class examples, application to design project
	Teamwork	Possibly	Moderate	Students work in teams often, class discussions are used to encourage student familiarity
	Planning	Yes	Moderate	In-class examples and planning activities
	Concept generation	No	Complex	In-class concept generation exercises
Emerging Technology	Applications/uses	Yes	Basic	Introduce physical examples
	Governing physics	Yes	Moderate	Conceptual physics with basic governing equations
	Processing/ fabrication	Possibly	Complex	Hands-on lab experimentation
	Limitations/ problems	Yes	Complex	Real-world cases, lab demonstrations
Design Project	Planning for design	Yes	Moderate	Long-term design project
	Concept generation	Possibly	Complex	Real design problem
	Apply emerging technology	Possibly	Complex	Examples of emerging technologies in existing products
	Presentation of ideas	Possibly	Moderate	In-class discussions, one-on-one meetings with instructor

4. Course Description

The motivation behind the current proposal stems two-fold from the areas covered in the course. First, emerging technologies offer opportunities for new and exciting scholarship in the classroom, considering that there is a greater potential for innovation and development within an emerging technology research area. Second, an opportunity is presented to involve the students in purposeful design, while simultaneously pushing the boundaries of engineering design ideas. The current design course focuses on teaching the significance of fully developing and understanding each of the six stages of design while emphasizing the importance of the initial planning stages [13]. This course also has the goal of strengthening the student's planning skills along with their ability to design within a team, primarily by engagement in a first-hand experience by working through a design project.

As discussed above, the primary objective of this course proposal is to fill an engineering design gap found in the middle years of engineering curriculums in U.S. institutions. By tailoring specific sections of the course to the instructors research interests, students will be exposed to areas of technology which they might not have access to by other means. Several specific course learning goals along with their related sub-goals; referred to here as learning objectives; have been developed with the help of [11] and [12] which seek to identity the important aspects of the previous discussion and are presented in Table 2. Along with each learning goal and learning objective is the type of learning which is targeted.

Table 2. Example course learning goals and objectives

Learning Goals	**Type of Learning**	**Nested Learning Objectives**	**Type of Learning**
Understanding/ application of the mechanical design process	Habits of mind/Complex Thinking	Students will be able to effectively work through the product planning stage of design	Application (Cognitive)
		Students will be able to classify customer requirements and translate them into measurable engineering metrics	Analysis (Cognitive)
		Students will be able to formulate connections between the design process and general problems, in and out of engineering	Synthesis (Cognitive)
Relevant working knowledge of the emerging technology	Information processing	Students will be able to identify different composite materials and the associated strengths/weaknesses	Comprehension (Cognitive)
		Students will be able to explain the different composite fabrication/manufacturing processes	Comprehension (Cognitive)
		Students will be able to calculate material properties based on constituent materials	Analysis (Cognitive)
		Students will be able to discuss the current limitations and areas of improvement	Comprehension (Cognitive)
Synthesis of technical knowledge with critical application to a design scenario	Complex thinking	Students will identify a technology area where composite materials could be potentially useful	Application (Cognitive)
		Students will develop and create a new design/product by combining current technical expertise with new composite material technology	Synthesis (Cognitive)
		Students will perform self-evaluation and analyze other groups design ideas and ingenuity	Evaluation (Cognitive)
Enhancement of the students ability to communicate ideas and information	Effective communication	Students will brainstorm collaboratively with team members to generate design ideas	Social (Affective)
		Students will have the opportunity to present their ideas and final design solution to the class	Social (Affective)
		One-on-one meetings with the instructor will be used to discuss progress and gauge understanding	Motivational (Affective)

The ideas presented in Table 2 are illustrated here through two examples to better identify the core principles involved in teaching design theory. The third nested learning objective of the first learning goal reads "students will generate several conceptual ideas which solve a problem." To support this learning goal, the students will utilize the 6-3-5 method [13]. First, the students are organized into groups of six. The students will then be asked to individually generate three conceptual ideas in five minutes for a new desk design that addresses the needs of current college students. The design criteria will be that the desk must be easy to move, easy to sit in, have internet access and a power strip, have room for a laptop computer, and will not be outdated in five years. The conceptual ideas will be drawn by the students on a piece of paper, and the papers will be passed around the group incrementally every five minutes in accordance with the 6-3-5 methodology. After completing this cycle, the team will briefly evaluate the ideas and share their best solutions with the other groups in the course. Next, consider the first nested learning objective of the third learning goal, which states that "students will identify a technology area where composite materials are not currently used but could be useful." As an example, the benefits of lightweight composites could be added to the structure of a car to reduce the total weight and increase acceleration and top speed capabilities. In addition, the fact that composites can be molded into complex shapes could be used to design intricate exhaust manifolds for an engine to replace the limitations of steel. These examples demonstrate specific class activities which can be implemented to support the course learning goals.

The focus of the learning objectives is centered on a design assignment involving teams of three to five students. The project description is intentionally broad, to encourage creativity and a wide range of different design avenues for each of the student teams to take. The specific project description is given as follows:

> "Using what you [the student] know about design and composite materials, choose an engineering design or product which could benefit from the application of composite materials. Alternatively, choose a customer need for which there is no solution currently available which could be fulfilled by developing a design which utilizes composite materials. The only requirement is that the final design must consist of at least 25% composite materials. You and your team of three to five other engineers will work through the first four stages of design as stated by Ullman [13] (product discovery, project planning, product definition, and conceptual design) in detail throughout the remainder of the semester. Aspects of the design process which have been stressed in this course should be reflected in your design team's methodology and approach to the problem. To culminate the course, a final report will be turned in to the instructor and a presentation will be made to the class regarding your design process and final design."

The above project statement reflects the primary learning goals of the course, where the project is intended to be the culmination of the course requirements. In addition to the above course description and project statement, Appendices A and B present more detail regarding a sample course topical outline, recommended course textbooks, and an outline for overall course grading.

5. Course Approach and Instructional Methodology

The course learning goals presented in Table 2 are important to keep in mind as more specific aspects of the course are further outlined below. The model of teaching best describing the instructional approach taken here is termed a constructionist, problem-based teaching model. The syntax of the course is further outlined in Table 3, guided by [12].

Table 3. Specific structural elements of the course learning goals

Learning Goals	Instructional Strategies	Instructor Actions	Student Activities
Understand and apply the entire design process	Lecture, discussion, case-study	Relay learning objectives	Focus on learning objectives
		Present short examples	Work through examples to experience designs processes
Relevant knowledge of emerging technology	Lecture, lab demo, discussion,	Relay important technical information	Digest key components of emerging technology
Critical application of new technical knowledge to a design scenario	Group project, discussion	Elicit performance	Perform
		Challenge commonplace designs	Push personal boundaries of design possibilities
Enhance students ability to communicate ideas	Team presentation and report	Give informative feedback	Reflect on feedback
		Give constructive feedback	Apply feedback

Other important aspects of the instruction process involve the social system, the role that the instructor plays in the classroom, and the support system in place to assist the students' needs. The social system is vital and plays an important role in setting the context for learning. It also molds the learning dynamic and the level of approachability which the instructor exhibits. The instructor must also have a well defined role within the classroom to give stability and structure to the course. A support system which reinforces and guides the learning goals of the course is essential for the success of the individual students enrolled. Table 4 presents a summary of these ideas applied to the current course development, under the direction of [12].

Table 4. Aspects of the classroom and instructional dynamics

The social system The interpersonal structure of the classroom	A blend of "social" and "radical." The students will be required to cooperate significantly and will also be responsible for much of their learning experience as it will be mostly experiential in nature during the design project.
The role of the instructor How the instructor relays information and enables learners ability to grow	The first half of the semester will be approached as both an instructor and a mentor. The second half of the semester will be focused on the design project, where then the mentoring role will come into play more often. Significant cooperation among the students in their design process will be encouraged.
The support system The types and amount of instructional, technical, and other resource support required for the instruction	Case studies from the composite materials textbook
	Simple problems to demonstrate composite material physics
	Small quizzes periodically to gauge progress near the beginning of the course
	Seven week design project
	Software for solid modeling and structural dynamics (e.g. COMSOL, ANSYS)

Particular aspects of the instructional approach towards the course were adopted from a presentation at Virginia Tech sponsored by the Faculty Development Institute taught by Dr. Brett Jones [15]. Dr. Jones has developed an instructional model which was designed to help faculty better prepare course activities to motivate students, referred to as MUSIC, which stands for eMpowerment, Usefulness, Success, Interest, and Caring [16]. The details of each of these ideas of expanded in Table 5, with some specific examples included to demonstrate potential instructor behavior to support these classroom conditions.

Table 5. MUSIC model of instruction [15] applied to the current course

e**M**powerment	Let students have partial control over learning outcomes and course format	During the first class ask the students for suggestions about course rules and guidelines about discussions and grading policies
	Avoid manipulating students behavior or design outcomes	Encourage students to reach into areas where they may be unfamiliar with the topic
Usefulness	Relate course content to students interests	Composites used in race cars, wind turbines, boats, helicopters, etc.
	Make the connection between course material and career goals	Emphasizing planning creates a better product and saves the company money in the long-term
Success	Clearly outline classroom and individual student expectations	Regular quizzes regarding course material
		Syllabus contains all course policies and due dates
	Give regular feedback regarding students competence and progress	In-class discussions
		One-on-one meetings at the semester's beginning
Interest	Interject humor and/or novelty into discussions	
	Show defined enthusiasm for course content	
Caring	Demonstrate specific care about students well-being	
	Encourage the students' success	

6. Course Assessment

The methods implemented in this report for assessing the current course were developed using the resources of Heywood [6] and Leydens et al. [17], along with the resources previously mentioned found in [12]. Chapter 15 of the text authored by Heywood [6] presents a rigorous study involving the assessment and evaluation of engineering education courses. As this study points out, many instructors are noticing the need for more qualitative assessment methods within the engineering education context, as opposed to a purely quantitative approach. Leydens et al. [17] continue this discourse into more detail and provide an excellent resource for designing qualitative assessment measures within the classroom. The method found to be most applicable to measure the current course outcomes is a "mixed" approach, which uses qualitative and more open-ended studies to identify specific topics of interest regarding the course, which can subsequently be broken down into quantitative questions as a broader, follow-up survey. This balancing of two alternative methods is an excellent approach for establishing both "breadth and depth" within the evaluation technique. Table 6 presents specific assessment strategies developed for the current proposed design course.

Table 6: Course learning goals and strategies

Goals	Sub-Goals (Objectives)	Type of Learning	Assessment Strategy	Feedback Strategy
Understanding and application of the design process	Students will be able to effectively work through the product planning stage of design	Application (Cognitive)	Design project and product planning	Discussion, feedback from group members
	Students will be able to take customer requirements and convert them into engineering metrics	Analysis (Cognitive)	Product definition stage of project	Discussion, in-class examples, graded quizzes
	Students will generate several conceptual ideas which solve a problem	Synthesis (Cognitive)	Quizzes, and conceptual idea generation	Grading, discussion, group members
	Students will be able to connect and apply the design process to general problems, in and out of engineering	Synthesis (Cognitive)	Discussions and design project	Discussion, grading
Relevant knowledge and appreciation for emerging technology	Students will be able to identify different composite materials and the associated strengths/weaknesses	Knowledge (Cognitive)	Quizzes, design project: product definition	Grading, discussion
	Students will understand the different fabrication processes available for actual composite manufacturing	Comprehension (Cognitive)	Quizzes	Grading, discussion
	Students will be able to calculate material properties based on constituent materials	Application (Cognitive)	Quizzes	Grading
	Students will understand the current limitations and areas of improvement involved with composite materials	Analysis (Cognitive)	Quizzes, conceptual design	Grading, one-on-one discussions
Critical application of new technical knowledge to a design scenario	Students will identify a technology area where composite materials are not currently used but could be useful	Analysis (Cognitive)	Design project: product discovery	Discussions
	Students will develop a new product synthesizing current technical expertise with new composite material technology	Synthesis (Cognitive)	Design project: conceptual design	Grading, discussion, internal group review
	Students will assess others design groups ideas and ingenuity	Evaluation (Cognitive)	Student/teacher evaluations of presentations	Review of commenter's feedback
Enhancement of the students ability to communicate ideas and information	Students will brainstorm collaboratively with team members to generate design ideas	Social (Affective)	Evaluation of ideas by teacher/ other groups	Grading, discussion
	Students will have the opportunity to present their ideas and final design solution to the class	Social (Affective)	Presentations	Grading and viewer feedback
	Students will work together to produce reports and presentation materials	Motivational (Affective)	Design project	Grading and viewer feedback

A consistent method towards grading is also essential toward a successful assessment of the learning goals in the classroom. Furthermore, a specific outline of each step in the grading process along with precise grading criteria for each item is essential for framing the focus of the instructional outcomes and consistent assessment. Table 7, developed through [12], presents a sample grading rubric of particular sub-processes within the design project along with a brief description of each score. This grading rubric may be altered by the instructor to reflect other specific course requirements or activities which will be graded within the course, and to focus on the important parts of each individual assignment.

Table 7: Sample grading rubric for a subsection of the student project report

Criteria	Description and Associated Score			
	1	**2**	**3**	**4**
Design planning	Two or less of the items in Level 4 grade (on the far right)	Three of the items in Level 4 grade (on the far right)	Four of the items in Level 4 grade (on the far right)	Plan template, task sequence, cost prediction, GANNT chart, SWOT analysis,
Product definition	Identification of some customer needs, but not in measureable form, composite material benefits incorrectly applied	Identification of customer needs in product and engineering specs, but composite material benefits incorrectly applied	Identification of customer needs but not in measureable form and composite material benefits applied to a product advantage	Clear indication of customer requirements converted to engineering specifications organized in a house of quality
Conceptual design	Only one concept, incomplete idea	Two ideas, fairly well thought out	Three new ideas, at least one being innovative	Three ideas utilizing the benefits of composites, advancing limits of design

A summative evaluation plan is proposed for the evaluation of the course, to be implemented as described in the preceding section. Both instructors and students will benefit from this evaluation, which will be used to alter aspects of instruction and in turn will create a better learning environment for the future students who enroll in the course. Surveys, one-on-one interviews, and project grades will all factor into the overall evaluation of the course, supporting the idea of a mixed-method approach where both qualitative and quantitative assessment measures are employed. A sample evaluation technique through a course exit survey is described in more detail in Table 8, regarding the educational outcome of increasing the individual student’s ability to apply the design process towards solving a design problem. These survey questions are to be completed by the student after the project has been completed and the semester has drawn to a close. The answers to these questions will help to identity strong points in the course structure, what the students understand, and areas which are weak and need to be improved in course implementation.

Table 8: Sample exit survey questions regarding the design course learning goals

Questions to ask the student related to the nature of what he or she was asked to do.	1) How did you identify a customer need? 2) What types of planning materials did you use? 3) When defining the product, how did you create engineering metrics from customer requirements? 4) How many concept generations were you able to create? 5) Did the members of your group completely agree with decisions made throughout the design process? If not, how did you resolve any disagreements/conflicts?
How capable were specific activities at generating predicted outcomes?	1) Did trying to find a customer need allow you to feel in control of your project? 2) Did the example planning materials in class prepare you for the actual planning within the project? 3) Were you able to confidently take customer requirements and define engineering specifications? 4) Did the in-class exercises in concept generation help you to stretch your imagination in developing concepts for the design project?
What students learned, how satisfied they were with a lesson or course, and what changes they would recommend.	1) How have the in-class discussions helped you to grasp the design project? 2) How can the design process be applied to problems outside of engineering? 3) Do you feel like you could walk into a successful company such as GE or Toyota and begin working on a design project with confidence? 4) Reflect on how your perceptions of working in a team on a design project have changed/remained the same as a result of this design project.

7. Conclusions and Recommendations

A new design course has been proposed which combines the teaching of design theory and methods with emerging technologies in engineering fields. The course is structured to be applied to different engineering disciplines in general, and is also designed to be tailored to the individual instructor's field of research expertise or interest. Further, the design course is focused on junior-year level engineering undergraduate students, and aims to fill the current gap in design education prevalent between freshman and senior year in many engineering curriculums. The course, design experience, and assessment methods outlined in this paper have many proposed merits, but it should be noted that it is unproven in implementation. However, the benefits have been clearly outlined from the perspective of a recent undergraduate engineering student through personal experience, documented literature, and the views of influential peers within engineering education at Virginia Tech. The course in its current context has been described in detail here. It is recommended that several trial courses of the proposed course be offered in curriculums and the results of the course assessment be studied to determine the effectiveness of the course in achieving the desired outcomes. Using these results, additional modification to the proposed course should be implemented as necessary in order to achieve the science requirement of design education necessary for the 21st century engineer to succeed.

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Appendix A - Example of Course Topics

Week 1 Introduction to composite materials and design methods	Definition	Simply: two or more different materials used together to make a better material
	Past examples	Mud and straw = bricks
		Wood chips/saw dust and synthetic resin = particle board
		Cement, water, and crushed limestone = concrete
	Importance	Lighter, stronger, Tailored to individual application needs
	Applications	Wind turbine blades, helicopter rotors, airplane panels, car panels, tennis rackets, motorcycle helmets, boat hulls
	Industry use	Aerospace, energy, recreation, automotive
	What is design?	What is the goal? How do we get there?
		Example activity: have the students define design in one sentence
	Personality indicator test	(to be used for assembling project teams during the second half of the semester
Week 2 Selection and Fabrication	Current state of the art	Fibers (e.g. carbon-fiber, e-glass, s-glass, etc.)
		Resin (e.g. epoxy, polyester, etc.)
		Weave types (e.g. plain, twill, etc.),
		Processing (e.g. LCM, RTM, VARTM, etc.)
Week 3 Governing Physical Equations	Resin injection	Transport phenomena: Darcy's law
	Fiber microstructures	How do they affect the resulting composite material's properties and performance?
	Property calculation	Harmonic averaging techniques, law of mixtures
		Fiber orientation and weave layers
Week 4 Modeling and Production	Simulation of resin flow process in fiber preform	
	Reinforcement construction in RTM	
	Manufacturing and production considerations, Cost-benefit considerations	
Week 5 The design method	Why study design? Is design a well-defined process or an "art"?	
	How humans solve problems, Creativity	
	How human minds work/ Short-term vs. long-term memory	
	How humans process information	
	Six stages of design (as defined by Ullman [13])	
Week 6 Project Planning and Product Definition	Why is project planning so important?	
	What amount of time do successful companies spend on planning?	
	What specific steps should be taken in project planning?	
	Where do product definitions come from?	
	How do we gauge the relative importance of different products requirements?	
Week 7 Conceptual Design and Product Development	Solid models vs. drawings	
	Analytical vs. physical	
	Importance of communication, different modes of communication style	
	Effective methods of conceptual design within a group setting	
	Connections between sales-engineering-manufacturing-installation	
Weeks 8-13 Design Project	Design project is developed by each group incrementally	
	Majority of class time is used to meet with group members and discuss progress	
	Beginning of each class (10-15 minutes) is used to elaborate on different design elements to further enrich the instruction of the design process	
Week 14	Teams present entire design process and final product to class and turn in report to instructor	

Appendix B - Recommended Textbooks and Grading

The following texts are recommended to be used to aid in the instruction of the current design course focused on the emerging technology of composite materials:

- Ullman D.G., 2010. The Mechanical Design Process, 4th edition. McGraw Hill, New York [13].
- Barbero E.J., 2010. Introduction to Composite Materials Design, 2nd edition. CRC Press, Florida [14].

A majority of the new material in this design course will be encountered while studying the different aspects of the emerging technology. Barbero [4] presents an excellent text outlining composite materials and the basic elements surrounding this technology. The students will be able to use this book to better understand composite materials in order to best approach the design project during the second half of the semester. The text by Ullman [3] is utilized in a freshman course required by the Engineering Department at Virginia Tech and will therefore serve as a secondary textbook and useful as reference for the current proposed design course. Essential aspects of design and the design process will be covered during the lectures and discussions, where a few excerpts from this book will be used to supplement the main text by Barbero [4].

Grading:

<table>
<tr><td>10%</td><td colspan="3">Class participation in discussions</td></tr>
<tr><td>5%</td><td colspan="3">Demonstration of understanding of both the design process and emerging technology during one-on-one meeting with instructor</td></tr>
<tr><td>15%</td><td colspan="3">Conceptual weekly (during first seven weeks) quizzes related to course content</td></tr>
<tr><td rowspan="9">70%</td><td rowspan="9">Design Project</td><td>10%</td><td>Team work</td></tr>
<tr><td>10%</td><td>Project planning, documentation, and follow-through</td></tr>
<tr><td>10%</td><td>Definition of needs and engineering metrics</td></tr>
<tr><td>10%</td><td>Concepts generated to solve design problem</td></tr>
<tr><td>25%</td><td>Implementation of composite material technology towards solving the problem</td></tr>
<tr><td>15%</td><td>Presentation of entire process</td></tr>
<tr><td>10%</td><td>Report</td></tr>
<tr><td>5%</td><td>Calculation accuracy/validity</td></tr>
<tr><td>5%</td><td>Innovation and creativity in design</td></tr>
</table>