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Fostering an Entrepreneurial Mindset through a Sophomore-Level, Multi-Disciplinary, Engineering Design Studio Experience

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Abstract

First year, project-based, engineering design courses have become common within engineering curricula across the country. In our first year course, we intentionally lay the foundation for the development of an entrepreneurial mindset within the context of traditional project-based design experiences. In addition, engineering programs have traditionally incorporated a capstone design project during the senior year and this provides another opportunity for our students to demonstrate an enterprising attitude. However, there exists a gap in design opportunities as well as in opportunities to continue the development of an entrepreneurial mindset for many students between the freshman and senior year of their engineering education. To address this need, we have designed a sophomore level course that will foster an entrepreneurial mindset in our students through a team-based, multidisciplinary engineering design studio experience. In this course, students will build upon the lessons learned in the first-year course by engaging real customers to identify and define opportunities themselves based on a theme. They will then use a systematic design process to design, build, and test prototypes that address these opportunities and create value for their customers.

The purpose of this paper is to present the process to design this new course and to describe the course curriculum. For example, while studio courses are commonplace in architecture programs, they are not traditionally found in engineering curricula. Thus, best practices had to be found through identification of existing programs and benchmarking activities. Benchmarking of curriculum, studio pedagogy, and facilities were all important aspects of the development of this course. After benchmarking and reviewing the literature, we created the learning objectives and outlined a syllabus and course schedule for the design studio. Additional ongoing development activities have included garnering support from faculty and administration to incorporate the course into the core curriculum as well as assembling an external advisory board of industrial and entrepreneurial professionals to mentor students during their time in the design studio. Future papers will document implementation and assessment of the course.

Introduction

For many years, Lawrence Technological University has been a part of the Kern Entrepreneurial Engineering Network (KEEN). KEEN is a collaboration of universities across the United States dedicated to instilling an entrepreneurial mindset in their undergraduate engineering and technology students. KEEN provides financial and developmental resources to participating institutions to enable the growth of curricular and extra-curricular activities that enhance the entrepreneurial mindset in their students. Specifically, KEEN emphasizes the development of engineers that exhibit an "entrepreneurial mindset coupled with engineering thought and action expressed through collaboration and communication and founded on character." In support of this, KEEN has created a framework of student outcomes and example behaviors that may be used to inform the design of programs seeking to develop an entrepreneurial mindset. This framework may be seen in Figure 1[1].

Through KEEN funding, Lawrence Tech has engaged in a campus wide effort to create a program that seeks to transform the educational experience of our undergraduate engineering students into one that develops an entrepreneurial mindset as described by the KEEN framework. The overall strategy for incorporating entrepreneurial minded learning (EML) into the core engineering curriculum may be seen in Figure 2. Part of this effort has been the modification of the first year engineering course sequence as described by Gerhart et al[2]. The logical next step was then to make curricular modifications that enhance the development of the entrepreneurial mindset in the sophomore year. Using KEEN funding, Lawrence Tech is taking this next step through the development and institutionalization of a multidisciplinary, design studio course to be taken during the second year of the engineering curriculum. This course builds on the foundations of the first year and further incorporates aspects of opportunity identification, customer engagement, and the use of technical skills to engage in user-centered design[3]. Specifically, in this course, students will identify opportunities for engineering design themselves within the context of a design theme. Students will then engage real customers and identify solutions to these opportunities based on customer needs. Finally, students will design, build, and test working prototypes that create value for their customers. Throughout the design process, students must work in a team setting, manage a long term project, account for cost and market implications, and communicate to all stakeholders in written, verbal, and public presentation formats.

Course Design

Studio Format and Benchmarking Activities

Lawrence Tech has a rich history of incorporating innovative teaching strategies into the engineering curriculum with an emphasis on problem-based learning, active/collaborative learning, and entrepreneurial minded learning. However, in order to achieve the desired outcomes of the new course, innovative teaching strategies needed to be implemented within the context of a more "real world" experience. In addition, a pedagogy that enhances the entrepreneurial mindset and is designed for maximum student engagement and retention was desired. Upon consideration, the format of a studio course was chosen for the second year engineering design class. Studio courses are a unique format that typically integrate content delivery, hands on activity, and discussion into one scheduled class period held in a single room. Often classroom space is dedicated for studio instruction and is specifically designed to be flexible to enhance collaboration and innovation. Lecture is de-emphasized while experiential learning and the production of "real world" artifacts using a structured design process are stressed. Given the practical nature of studio courses, they often require more contact time than traditional engineering courses. In fact, studio courses are often limited to less than 30 students and team-taught using two or more faculty[4].

While studio courses are commonplace in architecture programs, they are not traditionally found in engineering curricula. Thus, the first task in designing the new course was to benchmark existing programs to look specifically at courses, logistics, campus facilities, and teaching spaces[3]. External programs at the MIT Media Lab, Olin College, Worcester Polytechnic Institute, Stanford, and the University of Washington were visited and the development team met with faculty and administrators at each of these institutions. Common threads from the benchmarking visits helped the development team decide on many aspects of course design. For example, designating a relevant, user-oriented design theme for the students and allowing them to work within that space as they identify opportunities was a common practice designed to encourage student ownership and was seen on all of the benchmarking visits. Celebrating the accomplishments of the students at the end of the studio experience through contests and/or expositions that include faculty and industrial representatives has also become part of our new studio course because this was noted as a best practice during these benchmarking visits.

One important aspect of the benchmarking visits pertained to the design of studio facilities. Lawrence Tech is completing the construction of a new Arts, Sciences, and Engineering complex that will house two studio spaces dedicated for the sophomore studio courses. As such, the development team was very interested in benchmarking some existing studio spaces. From the benchmarking visits to Stanford, the University of Washington, and Olin College, the development team saw firsthand how designing studio space and furnishings for maximum flexibility and making important technical tools such as rapid prototyping equipment readily available encourages innovation and collaboration. In addition, all of the benchmarking visits emphasized the importance of having campus shop facilities and maker spaces easily accessible to the students during their time in the studio but also as a way of nurturing the entrepreneurial mindset as a part of the campus culture.

The architecture studios on the Lawrence Tech campus were also used as benchmarking resources and proved invaluable with regard to understanding pedagogy and student assessment in studio formats. In particular, the practice of formal and informal reviews at various points in the development process and guidelines for assessing these reviews were gleaned from these architecture studio visits. Finally, the design of the new entrepreneurial engineering studio course benefitted greatly from the input of faculty at other KEEN schools, and instructors of entrepreneurship courses, freshman introductory courses, and senior design courses on the LTU campus. Best practices gleaned from all of these benchmarking sources have shaped the design of the new sophomore studio course at Lawrence Tech.

Learning Objectives

Using the data gathered through the benchmarking activities, the goals of the LTU engineering curriculum, and the KEEN framework shown in Figure 1, learning objectives were identified for the sophomore studio course. As mentioned previously, this new course is intended to build upon the foundation established in the freshman year for the development of an entrepreneurial mindset. Specifically, students in the sophomore studio are expected to identify opportunities and define problems themselves, interact with real customers, and design, build, and test prototypes that create value for these customers. In addition, project management, communication, teamwork, and market analysis skills need to be developed in this course to prepare students for their senior capstone projects and future careers. Bringing all of these aspects together, the following learning objectives were identified. By the end of the semester, the student will be able to:

1. Generate, screen, and select promising design opportunities.
2. Organize, plan, and manage a long term engineering project within a team environment.
3. Identify and communicate the value of a design in terms of economic, professional, personal, and societal value.
4. Translate customer feedback into design specifications.
5. Utilize a systematic design process in order to bring a project to fruition.
6. Identify and utilize technical tools and skills needed to create a viable design solution.
7. Account for cost, value, and market implications at all stages of development.
8. Communicate design status and results to all stakeholders in verbal, written, and public presentation formats at appropriate points in the development timeline.

Once these learning objectives were created, they were mapped to the KEEN framework in Figure 1 in order to gauge how effectively these objectives support the development of an entrepreneurial mindset. Figure 3 shows these learning objectives mapped to the KEEN student outcomes/example behaviors used as indicators of an entrepreneurial mindset. Through the established learning objectives for this new course, all of the KEEN student outcomes are addressed at some point throughout the semester.

Course Overview

Having established the learning objectives for the course, work began to develop the layout of the course in terms of content and scheduling. Since the students will be engaged in a systematic design process from ideation and opportunity identification through building and testing prototypes, it made sense to structure the course in stages that mirror the stages of the design process. The content needed for each stage could then be spread progressively through the course and delivered at the appropriate points in the design process when students are ready to apply the concepts. This format fit well with the chosen studio format and the need to scaffold student learning as they work through a semester long project. Appendix A contains the syllabus created for the new studio course. A weekly overview of the topics covered during the semester may be seen in the syllabus.

Also as seen in the syllabus, student work is assessed through four milestone reviews in which students will present their work in a formal, public presentation in front of peers, instructors, industrial advisers, and faculty guests. This was a practice learned from architecture studios at Lawrence Tech. These milestone reviews occur at the Project Pitch, Concept Selection, Pre-build, and Working Prototype stages within the design process. The final review will be done in an expo format with faculty and industrial advisors. At the expo, students will present a poster and demonstrate their working prototypes. Less formal reviews occur throughout the semester and other summative assessments include reading quizzes, frequent update meetings with instructors, a project binder that documents the entire development process, and an e-portfolio on Innovation Portal (www.innovationportal.org). Of course, given the studio format of the course and the frequent interaction between student teams and instructors, formative assessments may be done easily as the semester progresses.

One important aspect of the entrepreneurial engineering design studio course is the design theme for each semester. Providing the students with a theme serves to focus their thinking while still making it possible for the students to identify opportunities for design on their own. A theme must be carefully chosen such that there are a variety of opportunities within the theme and reasonable access to real customers related to that theme within the students' environment. The theme must also be relevant and engaging for the mostly millennial generation of students enrolled in the studio course. Taking these factors into account and based on input from a myriad of potential customers on the LTU campus, the theme "Accessibility on Campus" was chosen for the first section of the new studio course. Thus far, this theme has been quite appealing to the students.

Course Assessment

In order to assess the efficacy of the course in the development of an entrepreneurial mindset, several methods of assessment are planned. First, students will take a pre- and post- course survey to measure changes in mindset brought on by participation in the course. Also, after each milestone review, time to reflect on the learning process is built into the course calendar. This time will involve the students writing a reflective essay and participating in a group discussion session. Finally, toward the end of the semester a focus group will be conducted by a faculty member who is proficient in entrepreneurial minded learning but not a course instructor. The goal of bringing in an outside faculty member for the final focus group is to allow the students more freedom to express their opinions on the studio experience.

Future Work

Lawrence Technological University is currently offering the first section of the entrepreneurial engineering design studio as a pilot course using two 2.5 hour studio sessions per week. This section contains 17 students with two instructors. This self-selected group is very engaged in the course and highly motivated. Lessons learned from this pilot section will be incorporated into the course in preparation for offering multiple sections of students. However, one challenge for future development will be scaling up this course to accommodate all engineering sophomores at Lawrence Tech. Specifically, maintaining consistency across multiple sections, identifying qualified instructors for multiple sections, and managing a large number of student projects each semester are areas that must be addressed as the course is further developed. The architecture studios at Lawrence Tech have successfully scaled up their studio format and lessons learned from colleagues teaching architecture studios are already proving helpful as these issues are addressed.

Conclusion

Through work done by KEEN, more than 100 corporate leaders were asked "What behaviors and competencies do you want in your new engineers…?" The combined responses may be summarized as "…confident, competent, open-minded engineers who effectively work on teams that employ experimentation, analysis, and innovation to create and promote solutions that are truly responsive to customers around the globe."[5] Lawrence Tech seeks to produce such engineers in part through the development of a second year course that will foster an entrepreneurial mindset in our students through a team-based, multidisciplinary engineering design studio experience. This course has been systematically designed in such a way as to allow students to practice their developing technical skillset within the context of a semester long design project. As part of the process, students will identify opportunities for design on their own and create value based on interaction with real customers. Thus, they will combine their skillset and their developing entrepreneurial mindset throughout this unique sophomore engineering studio course.

Acknowledgements

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References

1. *KEEN Engineering Unleashed*. Kern Family Foundation, 2015. Web. 25 Jan. 2016. <http://keennetwork.org/about-keen>.
2. Gerhart, A.L., Carpenter, D.D., Fletcher, R.W., Meyer, E.G. (2014) "Combining Discipline-specific Introduction to Engineering Courses into a Single Multi-Discipline Course to Foster the Entrepreneurial Mindset with Entrepreneurially Minded Learning." *Proceedings of the 2014 American Society for Engineering Education Annual Conference and Exposition*, Indianapolis, IN.
3. Vaz, M.J. and Carpenter, D.D. (2014) "Expanding Entrepreneurial Minded Learning to Incorporate an Enterprising Attitude in Undergraduate Engineering Students." Proposal to the Kern Family Foundation.
4. "Teaching Studios." *Cornell University Center for Teaching Excellence*. N.p., n.d. Web. 25 Jan. 2016. <http://www.cte.cornell.edu/teaching-ideas/labs-studios-discussions/teaching-studios.html>.
5. "Engineering with a Can-Do Attitude." *KEEN'zine* Oct. 2015: 4-5. Print.

Figure 1: KEEN Student Outcomes and Example Behaviors

EXAMPLE BEHAVIORS

CURIOSITY

DEMONSTRATE constant curiosity about our changing world
EXPLORE a contrarian view of accepted solutions

CONNECTIONS

INTEGRATE information from many sources to gain insight
ASSESS and **MANAGE** risk

CREATING VALUE

IDENTIFY unexpected opportunities to create extraordinary value
PERSIST through and learn from failure

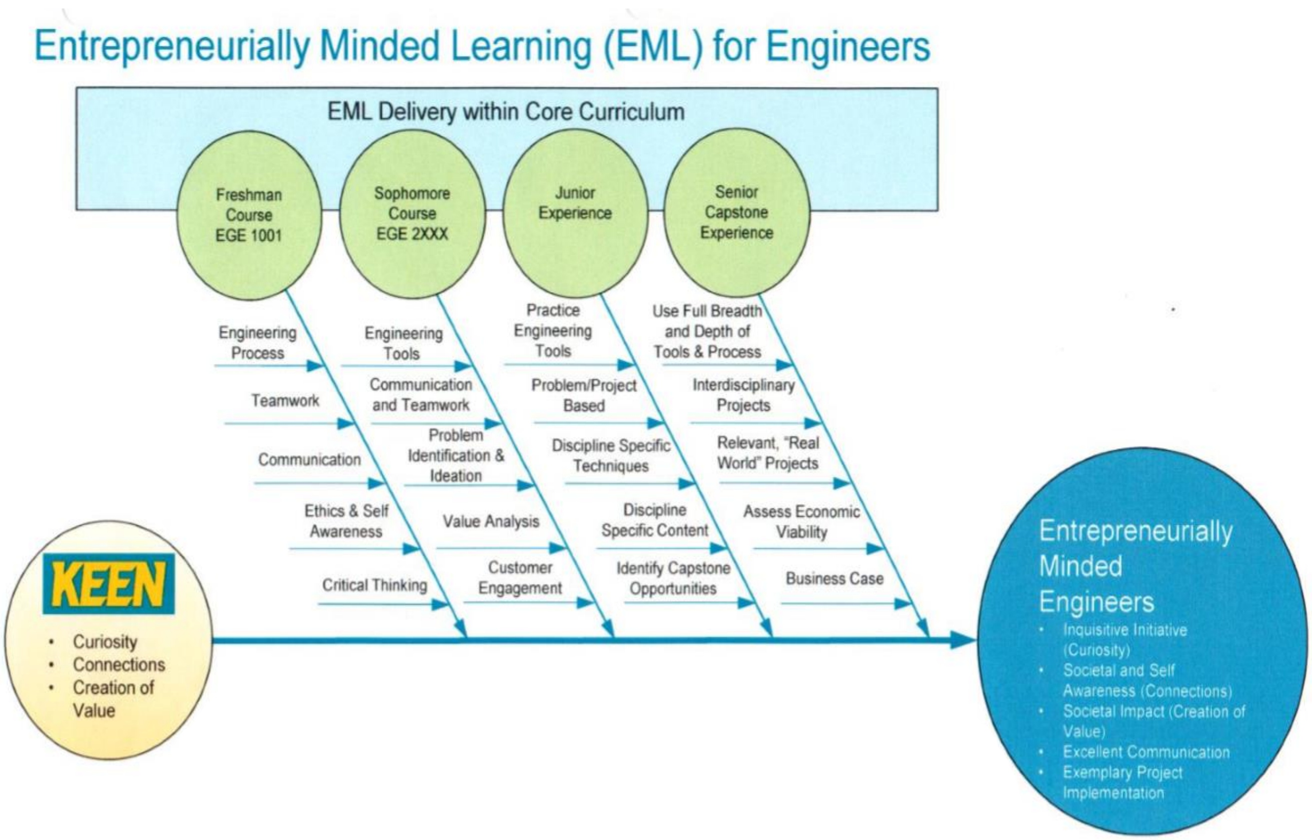
APPLY creative thinking to ambiguous problems
APPLY systems thinking to complex problems
EVALUATE technical feasibility and economic drivers
EXAMINE societal and individual needs

FORM and **WORK** in teams
UNDERSTAND the motivations and perspectives of others

CONVEY engineering solutions in economic terms
SUBSTANTIATE claims with data and facts

IDENTIFY personal passions and a plan for professional development
FULFILL commitments in a timely manner
DISCERN and **PURSUE** ethical practices
CONTRIBUTE to society as an active citizen

Figure 2: Overall Strategy for Implementation of Entrepreneurial Minded Learning within the Core Engineering Curriculum



(Diagram originally created by Mr. Thomas DeAgostino, former Director of the Studio for Entrepreneurial Engineering Design)

Figure 3: Course Objectives versus KEEN Student Outcomes in Sophomore Entrepreneurial Engineering Design Studio

KEEN Student Outcomes	Learning Obj. (1)	Learning Obj. (2)	Learning Obj. (3)	Learning Obj. (4)	Learning Obj. (5)	Learning Obj. (6)	Learning Obj. (7)	Learning Obj. (8)
Demonstrate constant curiosity about our changing world								
Explore a contrarian view of accepted solutions								
Integrate information from many sources to gain insight								
Assess and manage risk								
Identify unexpected opportunities to create extraordinary value								
Persist through and learn from failure								
Identify new business opportunities								
Apply creative thinking to ambiguous problems								
Apply systems thinking to complex problems								
Examine technical feasibility and economic drivers								
Examine societal and individual needs								
Form and work in teams								
Understand the motivations and perspectives of others								
Convey engineering solutions in economic terms								
Substantiate claims with data and facts								
Identify personal passions and a plan for professional development								
Fulfill commitments in a timely manner								
Discern and pursue ethical practices								
Contribute to society as an active citizen								

Key: Directly met by the course objective

Indirectly met by the course objective

Appendix A

EME4983: Entrepreneurial Engineering Design Studio
Syllabus – Spring 2016

TIMES: Mon/Wed 8:20 – 10:50 am

LOCATION: E109

INSTRUCTORS:	**CONTACT INFO:**	**OFFICE HOURS:**
Dr. Cristi Bell-Huff	Huff: cbellhuff@ltu.edu,	E98, Tu 2-3:30pm, F 9-11am
Ms. Heidi Morano	Morano: hmorano@ltu.edu,	E151, M 2:30-4pm, Th 9:30-11:30am

CREDIT HOURS: 3

CRN: 4603

COURSE DESCRIPTION: The Entrepreneurial Engineering Design Studio emphasizes creating solutions through team based projects utilizing engineering tools and skills, along with opportunity identification, ideation, value analysis, and customer engagement.

REQUIRED TEXT: *Product Design and Development*. K.T. Ulrich and S.D. Eppinger. 5th edition. McGraw-Hill. 2012. ISBN 978-0-07-340477-6

OTHER MATERIALS: 3" 3-ring binder with clear insertable cover pocket, 15 dividers, log book, CAD software

LEARNING OBJECTIVES

1. Generate, screen, and select promising design opportunities.
2. Organize, plan, and manage a long term engineering project within a team environment.
3. Identify and communicate the value of a design in terms of economic, professional, personal, and societal value.
4. Translate customer feedback into design specifications.
5. Utilize a systematic design process in order to bring a project to fruition.
6. Identify and utilize technical tools and skills needed to create a viable design solution.
7. Account for cost, value, and market implications at all stages of development.
8. Communicate design status and results to all stakeholders in verbal, written, and public presentation formats at appropriate points in the development timeline.

GRADING/EVALUATION

Course grading components will consist of:

1. Reading Quizzes – 5 pts each
2. Weekly status updates - 5 pts each
3. Pin Up Reviews - 10-20 pts each
4. Milestone Reviews and Mid-Project Review – 50 pts each
5. Final Project Binder – 150 pts
6. Final E-portfolio on Innovation Portal - 100 pts
7. Final Design Presentation – 50 pts
8. Final Design Demonstration – 50 pts

Records of Work in Progress:

Each student must be prepared to show work in progress at any time. This includes notes on discussion points and lecture topics, notes from team meetings and work sessions, review and milestone documents, ideas, sketches, and any other related material. Keep your materials organized. Periodic checks will occur.

Each team will be required to submit PDFs of all of their work as presented at reviews. The PDF will be due no later than 24 hours after the review or meeting. A final grade on any assessment will not be given until the PDF for that assignment has been received.

Project Binder Organization

The project binder will serve as a record of the entire design and development process that you have engaged in throughout the semester. The binder should contain dividers with sections clearly labelled and in the order shown below. File all documentation related to each stage of development in the appropriate binder section.

1. Executive Summary
2. Design and Development Team
3. Opportunity Identification
4. Mission Statement
5. Market Research/Identifying Customer Needs
6. Target Specifications
7. Concept Generation
8. Concept Selection
9. Project Management
10. System Level Design
11. Detail Design
12. Bill of Materials
13. Product Development Economics
14. Prototype Building, Testing, and Refinement
15. Final Product

E-Portfolio on Innovation Portal

You will create an e-portfolio on the Innovation Portal. This is a collaboration tool found at https://www.innovationportal.org/ . Each team member will have an account in the portal with ownership access to the portfolio. Instructors and advisors will have view only access to your portfolio and will be able to check your progress at any time throughout the semester. Details on the e-portfolio and creating accounts will be given in Week 3.

Late or Incomplete Work:

Late work will be accepted only at the discretion of the instructors and will be subject to grade reduction. If you have extenuating circumstances, speak with the instructors promptly. These types of circumstances will be considered on a case-by-case basis.

ATTENDANCE AND PARTICIPATION

Attendance is required for all class sessions and at all reviews. More than two absences may be grounds for failure at the discretion of the instructors. Participation in work sessions, discussions, reviews and meetings are essential to meeting the requirements for the design studio. If you have extenuating circumstances, speak with the instructors promptly.

ACADEMIC CONDUCT
The LTU Academic Honor Code prohibits all forms of academic misconduct. Academic misconduct refers to dishonesty in examinations (cheating), presenting the ideas or the writing of someone else as one's own (plagiarism) or knowingly furnishing false information to the University by forgery, alteration, or misuse of University documents, records, or identification. Academic dishonesty includes, but is not limited to, the following examples: permitting another student to plagiarize or cheat from one's own work, submitting an academic exercise (written work, printing, design, computer program) that has been prepared totally or in part by another, acquiring improper knowledge of the contents of an exam, using unauthorized material during an exam, submitting the same paper in two different courses without knowledge and consent of professors, submitting a forged grade change slip, or computer tampering. The faculty member has the authority to grant a failing grade in cases of academic misconduct without the chance of re-computation of GPA.

GENERAL PROJECT GUIDELINES (based on those described by Ulrich and Eppinger)

- The product should have demonstrable value based on customer needs.
- The product should be a material good not a service. You must produce a working prototype.
- The product should have a high likelihood of containing fewer than 10 components. At least one of the components in the final prototype must be produced using rapid prototyping technology.
- You should be confident of being able to prototype the product for less than $300.
- The product should require no basic technological breakthroughs. We do not have time to deal with large technological uncertainties.
- You should have access to at least 5 potential users of the product.
- At the end of the semester, students will be expected to deliver a complete project binder that documents the entire development process, an e-portfolio on Innovation Portal, a presentation for an expo with faculty/industrial advisors, and a working prototype to be demonstrated at the expo.

COURSE OVERVIEW

- Week 1: Introductions, Entrepreneurial Mindset, Design Process, Ideation around the theme
- Week 2: Opportunity Identification, Value Propositions
- Week 3: Team Formation, Identifying Customer Needs
- Week 4: Target Specifications, Mission Statements, Pitch Presentations, Milestone Reviews
- Week 5: Rapid Prototyping and 3D Printing, Concept Generation, Cost Analysis
- Week 6: Concept Screening & Selection, Concept Selection Milestone Review, Market Research & Benchmarking
- Week 7: Project Management and Planning, Setting Final Specifications, System Level Design
- Week 8: System Level Design, Electronics Prototyping Platform, Mock-up Prototype
- Week 9-10: Detail Design, Further Cost Analysis, Budget Review
- Week 10: Mid-Project Milestone Reviews
- Week 11-12: Prototype Building
- Week 13-14: Testing and Refinement
- Week 15: Final Presentations & Prototype Expo