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A NEW COURSE ON PRODUCT DEVELOPMENT FOR ELECTRONICS ENGINEERING TECHNOLOGY

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A NEW COURSE ON PRODUCT DEVELOPMENT FOR ELECTRONICS ENGINEERING TECHNOLOGY

Introduction

College-level engineering and technology programs across the US have been experiencing decreasing enrollments for the past several years.[1] This has not only been an issue for the Electronics Engineering Technology program at Texas A&M University but it is an important problem for the United States in terms of developing a new generation of innovators. One reason that our faculty has identified with decreasing enrollment has been an inability to interest young men and women through traditional engineering "selling points." Today's college-bound student's needs and interests are substantially different than thirty years ago. To this end, our faculty has worked over the past few years to find a unique selling proposition. By working with current and incoming students in the program, it was determined that the concept of a career in electronic product and system development (actually participating in the design and development of the devices they use every day) resonated better with new students. While this is not a new concept especially in mechanical and manufacturing programs[2,3], a literature search indicates that this idea is unique among electronics programs. In addition, based on efforts at other institutions, a focus in product development lends itself well to teaching students about entrepreneurship[4,5], something that many of our faculty have been promoting to our students for the last decade. Evidence shows that this new proposition is working as most of the students now graduating from the Electronics Program take engineering jobs in the product and system development sector, serving as applications engineers, product engineers, test engineers, and project managers.

With the change in how the program is presented to both new students and industry came an opportunity to overhaul the current curriculum and ensure that it optimally reflected a focus in product and system development. From a technical standpoint, the curriculum was very strong, emphasizing analog/digital electronics, power, embedded systems hardware/software, communications, instrumentation and control. These are all topics necessary for a career in electronic product and system development. However, through multiple meetings with the industrial advisory board it became clear that industry felt it very important that students be exposed to the corporate engineering, financial, and business side of product development through a formal course. Thus, through multiple cycles of industry feedback, a new course in product development was created and offered in Fall 2012.

While traditional engineering technology courses focus on the technical aspects of engineering, this course attempts to bridge the gap between the technical and business sides of product development. To develop this new course, the faculty visited with multiple industry experts in the area of product development. From these visits, a list of required topics was created including understanding the product development process from concept to close out, appreciating business financials, developing a complete business case, working with customers, and being familiar with intellectual property concepts. One issue that the faculty encountered early during the course development was locating a good reference text. Due to the variety of topics to be included, no single text book was found that could satisfy all of the course's needs. To solve this problem, a custom E-book was created through a popular academic publisher. By

using chapters from several business, marketing and engineering books, a text was created that suited the needs of the curriculum.

This paper will present the details of the product development course including the process used to develop the course, the process used to create a custom textbook, and an in-depth look at the course topics. The course involves a hands-on laboratory experience, and this will be presented as well. Finally, results from the course assessment and students comments will be discussed.

The Electronic Systems Engineering Technology (eSET) Program

As indicated above, the program has recently changed the curriculum to add an emphasis in the area of electronic product and systems development.[6] In addition, the name of the program is currently being changed from Electronics Engineering Technology to Electronic Systems Engineering Technology, or eSET. This was done to reflect the focus on products and systems. Initially, the curricular changes targeted the technical aspects of developing electronic products and systems. An analysis of modern commercial and industry products and systems demonstrates that most of today's devices have embedded intelligence, communicate in some way with external systems, and interface to the outside world through peripherals, sensors, and actuators. Thus, the technical content of the curriculum was divided into three primary tracks using both new and existing courses: analog/digital electronics and interfacing; embedded hardware and software systems; and wired/wireless communications. The courses in these tracks were then modified based on faculty and industry feedback to include topics related to product and system development. Next, team projects concentrating on particular aspects of product development were threaded into the technical curriculum to ensure that the students receive ample hands-on experience with the concepts they learn in lecture.[7]

To support the technical curriculum, a new laboratory facility was also created to enable product development. Through $250k in internal grants, the Product Innovation Cellar (PIC), which can be seen in Figure 1, was established in November 2012. This 3400 square foot facility contains all of the resources needed to support student teams working on product development projects including a twelve-station student workspace, a computer-aided design facility, an electronics fabrication shop, a mechanical fabrication shop, a parts store run by the program's local IEEE student chapter, and a multi-media conference room.

Figure 1 - The Product Innovation Cellar

Once the three technical tracks were established, a fourth product development track developed through industry feedback that focused on industry needs and best practices was added. Through multiple meetings with the eSET program's industrial advisory board, a list of relevant topics often neglected in technical courses was created. These topics were then divided into four courses: Engineering Leadership, Engineering Statistics, Electronics Testing, and the course discussed here, Product Development.

The New Product Development Course

Curriculum Development Process

Product development is a term that is widely used throughout the public and private sectors, and the eSET faculty quickly learned that there are a number of different definitions that exist. In order to begin the curriculum development, a significant amount of time was spent appreciating these differences and how to best define the overall content of the course. Of particular concern were the differences that exist from a technical perspective versus a business-oriented viewpoint. Even within the technical arena, there were variations in what product development meant when comparing software versus hardware oriented points of view.

The overall goal of the eSET Program was to create a course that encompassed all aspects of product development from ideation to termination (retirement), but to include both the engineering/technical aspects together with the important business elements. In so doing, the students would come away with a high-level appreciation of all aspects of product development and have a better appreciation of the non-technical factors that need to be considered especially for embedded intelligence based new products.

The eSET faculty development team first worked internally, leveraging the vast expertise of its members. The eSET faculty has approximately five years of industry/military/consulting experience in product development activities per member. Through compilation of this knowledge, an initial set of topics was created. The faculty team then spent time doing research into other courses that focused on product development both at the undergraduate and graduate level across the US. This exercise indicated that there were few if any courses that address the subject of product development in the manner that was desired by the eSET Program. Most courses included learning through case studies as the fundamental process or used product development concepts as a precursor to other design topics such as mechanical design and analysis. Program management and systems engineering concepts and topics were also included in the other courses that were identified. Although all of these topics are important, the eSET Program's goal was to focus exclusively on the product development life cycle and the processes used by industry to innovate, develop, support and terminate products within their companies.

With the fundamental framework in place, the eSET team then contacted a number of large and small companies in the Dallas, Austin, Houston triangle to set up meetings and Q&A sessions about their product development processes. In addition to size variation, the team was interested in having input from a range of different industry segments that were representative of the positions eSET students took upon graduation. Included in this set of industry visits and/or interactions were representation from the automotive, communications, instrumentation, power hand tools, industrial, transportation, health care, and safety and security segments.

The faculty product development team then created a draft syllabus and list of topics for the Fall 2012 course offering. These items were presented to the entire eSET faculty for their

review and input. In addition, faculty assignments were made for a number of the course topics and recommendations for guest speakers were made for several of the other topics. Based on these activities and input from the eSET faculty, it was agreed that an adjunct faculty member should be hired to be the course director/developer of the course for the first semester offering. Mr. Matthew Leonard, a NASA-JSC senior program manager agreed to work with the eSET Program in coordinating the activities and delivering the course. Mr. Leonard's background in space-worthy product development and sustainment and his access to similar engineers and business people throughout the NASA contractor community paid significant dividends in creating a valuable experiential learning opportunity for all the students who enrolled in the course. A number of examples were also integrated into the laboratory portion of the course as both examples and as assignments.

Electronic Textbook

Once the overall syllabus and list of product development topics was finalized, the eSET faculty development team then began a search for a textbook that would cover the breadth of topics to be included in the course. More than ten texts were identified for review by the team. Using a matrix that allowed each textbook to be evaluated in terms of the topical information to be presented in the course, the eSET faculty team assessed the appropriateness of all texts for the course. Although a number of the texts contained some of the topics, no one text included all of the items to be presented in the course. One of the major drawbacks of multiple texts was the perspective that was presented. Some texts focused primarily on the business aspects of product development with little real technical content, while others glossed over the business aspects to look almost exclusively at the engineering components/consideration/processes of product development.

In researching the potential texts for use in the new course, one of the faculty members worked with a representative from McGraw-Hill who recommended that the eSET Program consider an e-Book approach to creating a new text specifically for the course. After eliminating all the potential candidates, the eSET faculty decided to pursue this recommended approach. Using the matrix of topics covered by each textbook, appropriate chapters/sections were selected from seven McGraw-Hill texts. Based on this process, a reference text of approximately 500 pages was created and made available to the students through on-line purchase and download. The e-Book, although not totally complete, did provide a far better reference text than selecting one of the many hardback texts that were currently available from a wide range of publishers.

Essential Knowledge – Key Elements

In undertaking the development of the Product Development course, a team of interested faculty members was assembled. With over 30 years of products/systems development experience represented by these faculty members, the key educational elements from their collective private/public sector experience were developed and used as the starting point for the course.

Using this list as a baseline, two parallel interactions were accomplished to build on the fundamental knowledge required for this type of course. As one overall goal for the course was to make it applicable to all undergraduate students across the A&M campus (especially within the Mays School of Business), a strong emphasis was placed on integrating the fundamental business knowledge components into the course. The other emphasis was on interacting with

upper-level decision makers within large and small technical product development companies to appreciate their overall product development strategy.

The faculty members then began their external outreach for both review and expansion of the technical elements they had assembled as well as the addition of the business aspects necessary to have a complete high-level view of the product development life cycle from ideation to termination (product retirement) and an understanding of all the processes (e.g., stages and gates) included in technical product development. Visiting and interacting with a number of hardware- and software-oriented companies over the summer semester was very beneficial in better defining the key elements that needed to be included in the new ENTC 333 – Product Development course. These interactions also identified subject-matter experts willing to work with the ESET faculty to provide guest lectures and instructional materials. These essential knowledge elements then became the roadmap used to produce the overall course syllabus.

Course Topics

The Product Development course was broken into a series of topics based on the knowledge attained from the industry experts. These include:

- Product Development Life Cycle
- Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis
- Agile Product Development
- House of Quality
- Business Finance
- Time Value of Money
- Intellectual Property
- Risk Evaluation
- Fault Tree Analysis
- Failure Mode and Effects Analysis
- Concept Generation and Evaluation

Below, examples of these topics are discussed in more detail.

House of Quality (HoQ)

In one of the labs, students learned to use House of Quality (HoQ)[7] to process Voice of Customer (VOC) and derive system design requirements. Students learned that establishment of the correct requirements to meet the customer's needs is critical for the success of a product. After the introduction of HoQ, an example was presented. A real-world project was then presented to the students. The students built a House of Quality for this project. During this exercise, the students learned how to use HoQ to derive requirements, they also learned when in the product development process the requirements were derived.

Business Finance

One of the major business-oriented areas of product development that industry representatives strongly encouraged being included in the new course was the topic of finance. Having a good idea, converting it to a viable product are necessary, but definitely not sufficient to successful product development. In each business, large or small, financial aspects play an important role in all stages of new product development. Therefore, two individuals from a Texas-based small business provided guest lectures on the financial factors that must be

considered in new product development. Working with financial statements such as profit and loss, the guest speakers walked the students through a series of "what if" scenarios so that the students could determine an appropriate business decision and then justify their choice to the class. Through this interactive discussion process, all eSET students developed a better understanding about the impact financial and business decisions have on product development activities.

Time Value of Money

Throughout the product development life cycle, the time value of money plays a critical role in the decision processes surrounding the initiation, continuation, and termination of a product. Therefore the ENTC 333 course students required a fundamental understanding of the underlying principles associated with economic decision making processes. This is especially true because the newly defined eSET curriculum had removed a course on this subject that was previously taken from the Industrial Engineering department. The eSET faculty felt that engineering decision making was an integral part of product development and not a stand-alone subject treated totally out of context. Those private/public sector representatives contacted during the summer semester also agreed that Bachelor-level graduates needed to have a good underpinning of these concepts, but more importantly, they need to appreciate the impact they had on the product development life cycle and how these tools were used in the stage/gate architecture of product development.

One lecture and one lab were used in the new ENTC 333- Product Development course to present the fundamental concepts of time value of money and interest including:

- Present Value
- Future Value
- Annuity and Perpetuity
- Gradient
- Rate of Return, Interest, and Return on Investment
- Economic Decision Making Process

The laboratory exercise included review of the homework assignment made in class as well as randomly selecting time value of money examples contributed by the students as part of their pre-lab assignment. Terminology, assessment methodologies, and decision making results were also discussed during the lab session.

Although not as extensive as the content of the two-hour course in engineering economics offered by the IE department, the fundamental concepts were provided and understood, especially in the context of technical product development. This material, directly coupled with the information provided in the finance and accounting portion of the course, adds significant insight into the need to appreciate product development from more than just a technical perspective.

Intellectual Property

Intellectual property and IP protection are paramount to the product development process in all industry segments. The ENTC 333 course was fortunate to identify and successfully invite a patent lawyer from an IP law firm headquartered in Austin, Texas to provide a guest lecture on intellectual property (patents, copyright, trademarks, and trade secrets) in general and then to specifically speak about the American Invents Act of 2011 and how this legislation impacts

product development. Here again, understanding the non-technical factors associated with the product development life cycle provides each student with a better understanding of why certain "good ideas" are not pursued by a company or decisions are made to abandon new product work based on intellectual property ownership. Likewise, the concept of taking advantage of termination of IP rights to create new opportunities for product development was also highlighted during the guest presentation.

Risk Evaluation

Another class session was focused on risk and risk assessment as it deals with product development. Students learned how to use a decision tree to better understand and explain the element of risk in the product development decision making process. Because business must make a profit on the products it develops and sustains, risk assessment is an on-going function that can have significant impact on decisions made at the executive level. This higher-level evaluation process that considered more than just the technical aspects of a new product was a valuable learning experience for the students.

Industry Guest Speakers

In a number of cases, the eSET Program has been able to rapidly develop a new course by using guest speakers from the public and private sectors. Product development is an excellent opportunity to build a strong course through guest speaker involvement. A secondary benefit in building a course in this manner is the buy-in that comes from those individuals who become involved in the delivery of the content. Students definitely benefit from having industry representatives from companies they are interested in working with speak to them about how it really is "out in the real world", and faculty involved in the course development move up much faster on the learning curve of the wide range of topics included in a course such as this. Including both practicing engineers as well as business professionals gave the much desired breadth to the course which was in keeping with the overall goal. In several instances, the guest speaker also provided an assignment for some aspect of product development that small teams had to accomplish. The guest speaker would either return or interact with the student teams via a webex/skype remote interface to review and critique their work. This experiential learning process added increased understanding about many of the product development principles. Having case studies and examples taken from real world situations also increased the level of interest and involvement for the students.

Laboratory Component

Having a laboratory component for a course such as this allows for far more interaction between the students themselves and then between the student teams and instructor/guest speaker. The typical approach to the course was to discuss a small number of topics during the class session ending with a team assignment that was due in the following lab period. In some cases all teams worked on the same assignment, but in many cases the teams had totally separate assignments or different aspects dealing with the same product. Each team then was given time to present their findings and to answer questions from the other students and faculty members. In a small number of cases, student teams were assigned tasking at the beginning of lab and had to develop their perspective on that question or issue as part of the lab period which included a position paper on their on-line research findings. Having an opportunity to practice using a number of the tools and processes presented in class significantly reinforced the underlying

concepts and provided a far better appreciation of how interwoven the engineering and business aspects are to successful product development.

Course Project

In the fall semester to help accelerate the development of the course, the students were assigned a course project. The course project was an opportunity to have the students further explores product development practices. The students were tasked via homework assignments to research a product development topic, create a draft of a paper, create a final paper, as well as a presentation on the selected topic. This allowed the students to find one specific area of product development to focus on and then to demonstrate that knowledge in their final presentations to the class. These research materials will also be reviewed to determine if there is additional material that can be incorporated in future offerings.

As the course moves forward, the intent is to identify a small number of real products that are indicative of the eSET academic program. Once identified, small teams of students will disassemble the product into its various subsystems. Each subsystem will be evaluated and the students will determine how to improve each of the subsystems in terms of performance and/or costs. Finally the student teams will need to rebuild the entire unit so that it is a fully functional product. The Roomba and the Segway are two products under consideration at this time.

Results of First Offering

Student Survey

To assess the first offering of the Product Development course, a survey was created and administered to the students who completed the course in Fall 2012. Twenty-one of the twenty-three students enrolled in the course completed the instrument. The survey assessed multiple items including the students' perception of the importance of each of the twelve main topics in the course as it relates to product development and how well they thought each topic was presented in terms of their ability to learn. In addition, student satisfaction with the course was measured as well as their impressions of the two course projects. Finally, open-ended questions were used to solicit overall impressions of the course and to determine whether students felt there were topics that were included but not relevant and topics that were not included but needed. The results of the survey were then compiled and used to improve the Spring 2013 offering as discussed below.

First, when asked about their overall level of satisfaction with the course, the average assessment for the course was a 3.5 on a 5.0 scale. Student comments ranged from "a waste of time" to "very useful course that covered a lot." Anecdotally, the students that were in their Capstone design sequence indicated that in hindsight, they wished the Product Development course had been offered prior to starting their senior year. Considering this was a first offering of a course that is outside of the students' comfort zone, the faculty felt like the course was well received but had obvious room for improvement.

From the standpoint of individual topics, Figure 2 shows the importance of each topic as perceived by the students as it pertains to product development. Using a 3.5 as a cutoff, one can see that the students placed value on most of the topics in the class with the exception of Agile development, house of quality, and failure mode/fault tree analysis. In addition, when asked, most students felt that the lectures on agile product development did not add significantly to the course and could be removed. Student input also indicated that they felt the house of quality

lectures were important but needed additional attention as well as hands-on exercises to improve learning.

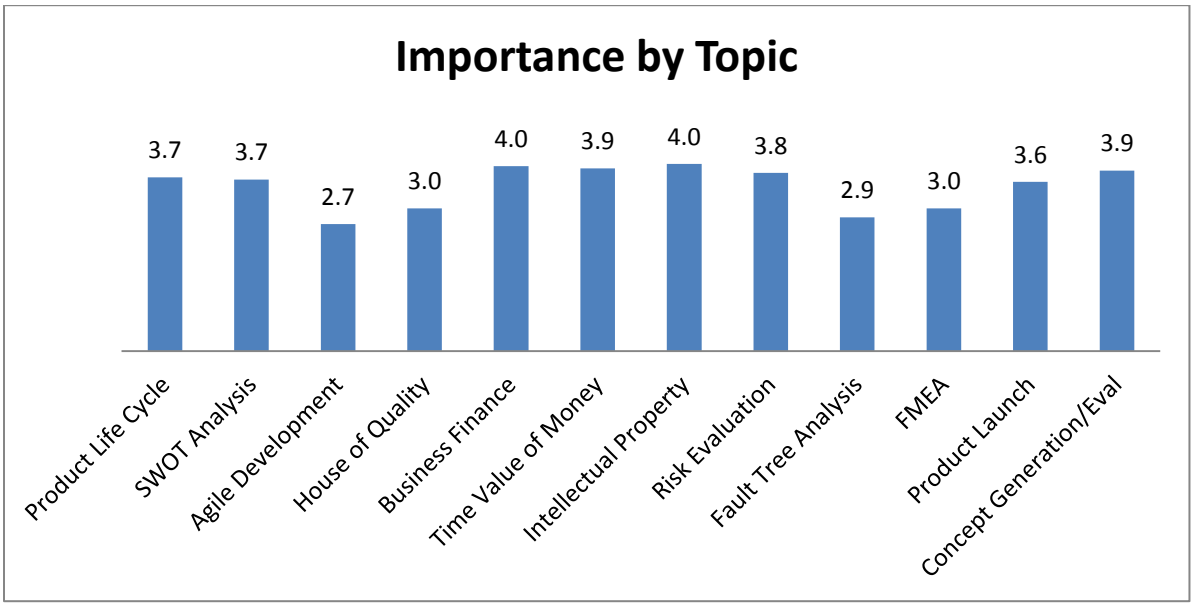

Figure 2 – Student survey results rating the importance of each of the listed topics to understanding product development

The students were also asked to evaluate the quality of instruction and presentation of each topic. This evaluation, as seen in Figure 3, was done since most topics were covered by different presenters. As expected, there was a strong correlation between the value a particular topic had to the students and how well they felt it was presented. One conclusion that was reached is that not all industry experts are capable of motivating student learning in a classroom/laboratory environment. However, it should be noted that because this was a first time offering, the guest lecturers were given substantial latitude in their presentations. In the future, additional care will be exercised in selecting appropriate guest lecturers and ensuring they have sufficient guidance prior to their presentation.

When asked for recommendations on additional or augmented materials, common themes from the student feedback indicated that both house of quality and SWOT analysis were very interesting but needed to be more fully explained and linked to an example project. In addition, students requested more information dealing with intellectual property and IP protection.

Students also indicated their expectation that the product development course should prepare them for their product development-oriented Capstone design experience. Recommendations were also received that one major project be used as a focus throughout the course and that small students teams be assigned portions of the entire project to leverage their time and understanding.

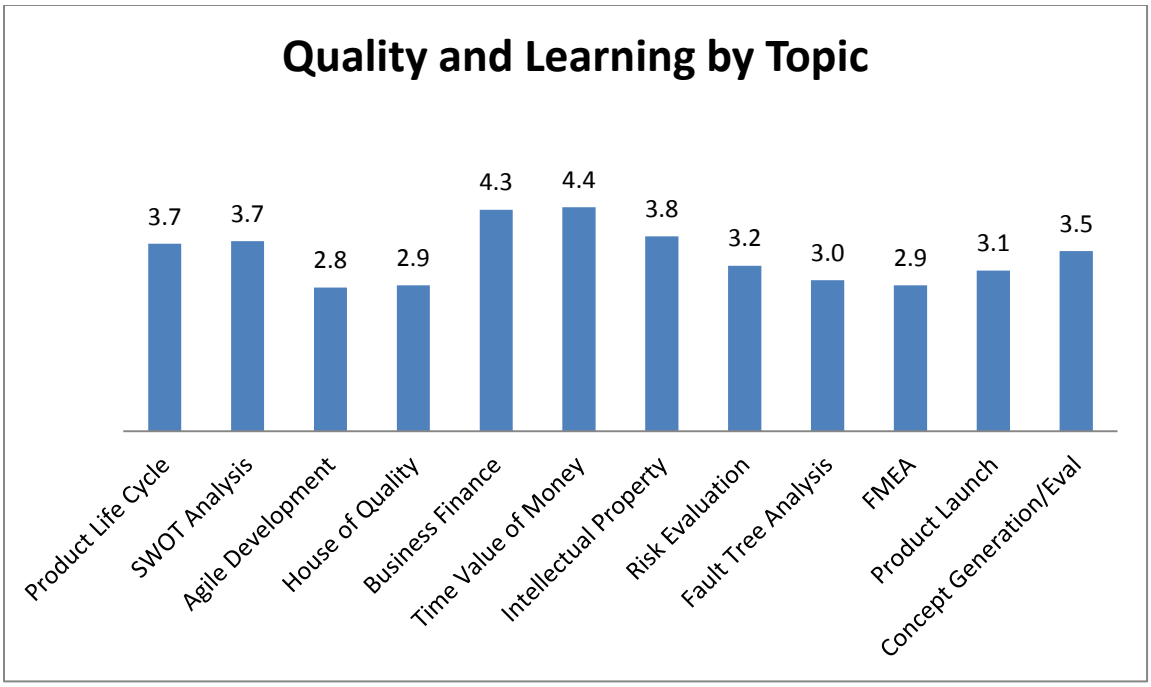

Figure 3 – Student survey results rating the quality of each of the listed topics as it relates to ability to learn

Industry Feedback

It should be noted that the whole concept for the Product Development course was industry-driven. Based on their feedback during Industrial Advisory Committee meetings, the faculty created a skeleton outline of the course and then, as indicated above, involved several different companies in the design of the curriculum. Once the course was finalized, the syllabus was vetted by industry partners. The response to the proposed course was overwhelmingly positive. In addition, because several of the lectures were presented by industry, anecdotal feedback from these presenters was solicited. One common thread from the industry feedback was their level of enthusiasm to work directly with the students, especially as it pertained to teaching those skills that industry value highly. In fact, based on their experiences in the first offering of the course, most companies have agreed to continue their support of the Product Development course next semester.

Summary and Future Plans

Summary

As part of an initiative to create an emphasis in product and system development, the eSET Program recently worked with industry to restructure their curriculum. An important element of the restructuring was the creation of a new course in product development. Through industry feedback, this course now offers an opportunity for students to learn about engineering best practices in product development and also gain insight on how the engineering and business facets within a company interact. Not only do they have the opportunity to learn these concepts in the classroom and hear directly from industry experts, but they also have the opportunity to put them into practice in an experiential laboratory setting.

In the Fall 2012, the course was offered for the first time. Anecdotal evidence indicates that the course was well received. However, additional work still needs to be done including course development, integrating the course into the Capstone design sequence, and integrating the course into departmental and university initiatives.

Additional Course Development

The initial offering of this course gave a rather generic exposure to the strategy of product development. The course fits well into the eSET Program overall curriculum and offers several enhancements to that curriculum. Based on survey feedback, several modifications of the course have been planned for the Spring 2013 semester including:

- The reverse engineering of a single electromechanical commercial product that includes wired and wireless communications. In addition to serving as the project for laboratory, the chosen product will also serve as the target example for each of the topics presented in class.
- Using a team-based methodology in the lab in order to more efficiently use student time and effort while highlighting the importance of good quality documentation and communication. This includes the opportunity for student teams to share their reverse engineering results, testing and data collection/analysis processes.
- The streamlining of the syllabus, removing topics that added insufficient value such as Agile product development while augmenting areas that were more relevant to the course such as House of Quality.

Having the course in the second semester of the junior year allows it to prepare students for their capstone design experiences. Using the product development processes on potential projects for the capstone series is being considered to mature the student's ability to have the concepts established for the capstone series at a much earlier stage.

Ideation for Capstone

One of the primary justifications for moving to a product development course at the second-semester junior year was the value-add proposition it provided to the Capstone design experience. All eSET students are required to successfully complete a two-semester Capstone project where a team of three to four students must transition a new product idea to a fully functional, pre-production prototype with full design and documentation, demonstration and delivery to an external sponsor/customer. Until the product development course was integrated into the curriculum, some students did not form teams or look for projects until the first week of their Capstone I semester. Because the product development course will become a prerequisite of Capstone I, students can begin thinking about their Capstone project, team, advisor, etc. earlier in their academic careers. Because ideation is critical to a successful Capstone project, having students form their own teams in the product development course and consider a larger number of potential projects increases the opportunity for success when they do enter Capstone. As the commercialization of products is more closely evaluated in during the product development course, projects will be selected based on their technical merit and on the potential for commercialization. Having more teams undertake projects with tangible commercialization potential will continue to increase the recognition of their capabilities and expand the industrial customer base for future teams.

Product Innovation and Development Initiative Activities

The Department of ETID received $200,000 funding to create a high impact learning environment for students. The three programs within ETID, Manufacturing and Mechanical Engineering Technology, Electronic System Engineering Technology, and Industrial Distribution, joined force and created the Product Innovation and Development Initiative (PIDI). The PIDI will focus on multidisciplinary product development effort by students from the three programs. Student workers will be hired to create products that can produce profits to make the PIDI self-sustainable. In addition, the PIDI projects will also be used as case study, labs, or capstone projects to provide more learning opportunities for ETID students.

University Initiatives

The new focus of the eSET Program and the associated activities in product development, innovation, applied research and entrepreneurship has resulted in a number of opportunities for collaboration. One such opportunity is with a new initiative being promoted by the Office of the Vice President for Research (VPR) known as Aggieland Startup. This University-level activity seeks to provide a campus-wide resource to support undergraduate business startup and entrepreneurship. Located in the Texas A&M Research Park, the facility offers opportunities for interaction, mentorship and development of student ideas for new businesses. The facility also offers opportunities for similarly-minded faculty to brainstorm and share ideas for multidisciplinary activities that deal with product/business development. The eSET Program has been a contributing member of this informal working group since its inception. With the realization of the product development course and the PIC, the eSET Program now brings a significant value to the table that has been lacking in the Aggieland Startup concept of operation.

First, having a product development course now available that can be taken by all Texas A&M students adds the ability to bring together the bright, energetic young minds of the over 40,000 undergraduate students. Working in multidisciplinary teams at the junior level is both motivational and rewarding. The eSET product development course and its syllabus are currently being used as a straw man for a college-level initiative to have Aggieland Startup underwrite the first of its kind, campus-wide course that can be taken by all students in their junior year. Ideas that come from this course for new technical products can then be transitioned to the Product Innovation Cellar.

Next, the ability to rapidly transition ideas into to fully functional prototypes is critical to the success of startup companies. Through association and partnership between the PIC and Aggieland Startup, this significant capability can be realized. Appropriately vetted and selected product ideas can be transferred to teams of undergraduate students who can then design, develop and test full-scale prototypes using the PIC design, development, mechanical and electronic facilities. The prototypes are then used by the Aggieland Startup student companies to demonstrate functionality necessary to garner financial support to move forward as a new venture. The relationship between the PIC and the Aggieland Startup initiative can be truly symbiotic.

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