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## **AC 2012-4756: DEVELOPMENT OF A WEB-BASED RAPID PROTOTYPING AND PRODUCT DESIGN COURSE**

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Yalcin Ertekin received his B.S. degree in mechanical engineering from Istanbul Technical University. He attended the Business School of Istanbul University and received a M.S. degree in production management. After working for Chrysler Truck Manufacturing Company in Turkey as a Project Engineer, he received dual M.S. degrees in engineering management and mechanical engineering from Missouri University of Science and Technology (MS&T), formerly the University of Missouri, Rolla. He worked for Toyota Motor Corporation as a Quality Assurance Engineer for two years and lived in Toyota City, Japan. He received his Ph.D. in mechanical engineering from MS&T in 1999 while he worked as a Quality Engineer for Lumbee Enterprises in St. Louis, Mo. His first teaching position was at the Architectural and Manufacturing Sciences Department of Western Kentucky University. He was a faculty member at Trine University. He is currently teaching in the Engineering Technology program at Drexel University. His area of expertise is in CAD/CAM, computer numerical control (CNC) machining, rapid prototyping, and quality control. His research interest includes sensor based condition monitoring of CNC machining, machine tool accuracy characterization and enhancement, non-invasive surgical tool design, reverse engineering, and bio materials.

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# Development of a Web-Based Rapid Prototyping and Product Design Course

## Abstract

This paper presents development of an integrated web-based rapid prototyping and product design course in the online Master of Science degree in engineering technology core discipline. The topics are aligned with a current trend for rapid product realization and information-integrated product design systems in industry, which currently includes rapid prototyping coupled with computer aided product design and development that provides zero-lead times in product conception and development. The main goal of the developed course is to simulate this real-life engineering development experience for our online graduate students who will work in teams to develop consumer products and at the end able to produce Acrylonitrile butadiene styrene (ABS) plastic prototypes using web-based remote log-in capability of the rapid prototyping machine. Hardware and software components are integrated with prototyping methodologies to achieve maximum effectiveness in teaching web-based prototyping concepts in ET615-Rapid Prototyping and Product design. The course includes theory and application of rapid prototyping technologies for new product conceiving, designing, manufacturing and testing. It also addresses the importance and examples of product design modeling and virtual prototyping. A survey of modern tools of digital prototyping and basics of solid modeling and Computer Aided Design-CAD technologies for prototyping are provided.

## Introduction and Background

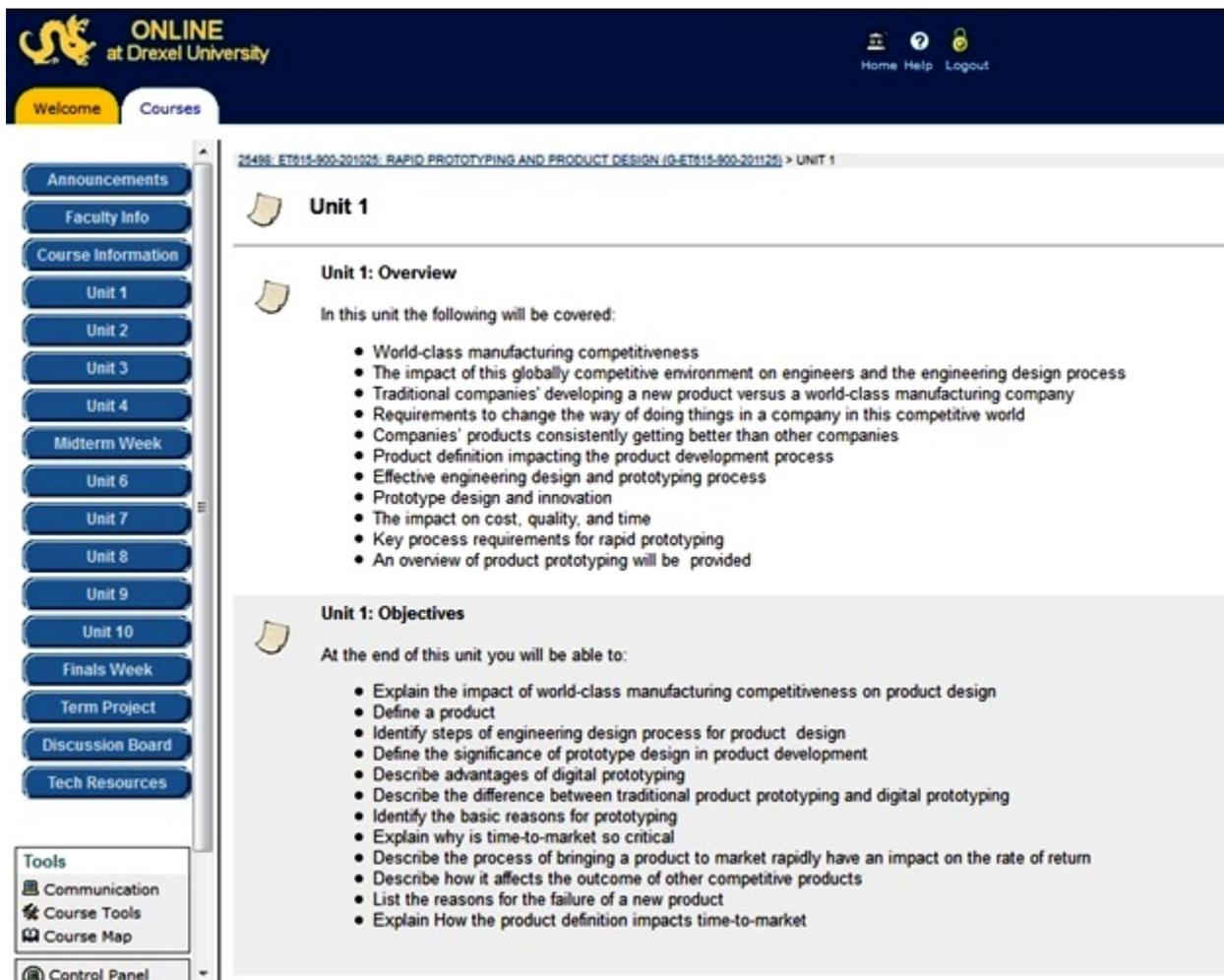
In 2010-2011, Engineering Technology program at Drexel University (DU) had started to offer an online Master of Science degree in Engineering Technology (MSET)<sup>1</sup>. This graduate degree program is intended to address the needs of the experienced industry professional. The program focuses primarily on the applied aspects of technology closest to product improvement, industrial practices, and interaction of engineering technology with operations. Students learn through real-time, remote or virtual labs to gain invaluable experience simulating real-world applications and settings. The M.S. in Engineering Technology program consists of 45 post-baccalaureate credits that are divided into three major segments: Core / Foundation Courses (27.0 Credits), Electives - (9.0 Credits), Capstone - (9.0 Credits). To achieve the goal of offering MSET degree, Engineering Technology (ET) faculty had to develop and implement learning modules that will include current industry best practices in the product development and manufacturing cycle. This curriculum also had to include aspects of design, analysis, and prototyping and improvement into selected coursework in each engineering technology discipline.

At the undergraduate level, many courses related to robotics, design, and materials are offered to the students in the Bachelor of Science in Engineering Technology program. Courses such as Robotics and Mechatronics, Quality Control, Manufacturing Materials, Microcontrollers, and Applied Mechanics can benefit from the laboratory experience in applications of mechatronics, robotics, and rapid prototyping. As well as helping in the teaching of various courses, such experience benefits students who are pursuing degrees in the engineering field. Students in the Mechanical, Electrical, and Industrial fields along with many others can learn many new skills from multi-disciplinary projects such as the rapid prototype design of consumer products, a

walking robot or various designs related to capstone senior design projects<sup>3,4</sup>. Such projects show students how to use different types of technology, and demonstrate how advanced technology can be used in an actual application. However, many of these courses are offered in face to face format and do not pose many challenges as it is more difficult to duplicate similar experiences for online students in the online graduate program. Overall, many different fields of engineering can benefit from this application, enabling the development of skill and knowledge in many different engineering aspects and processes.

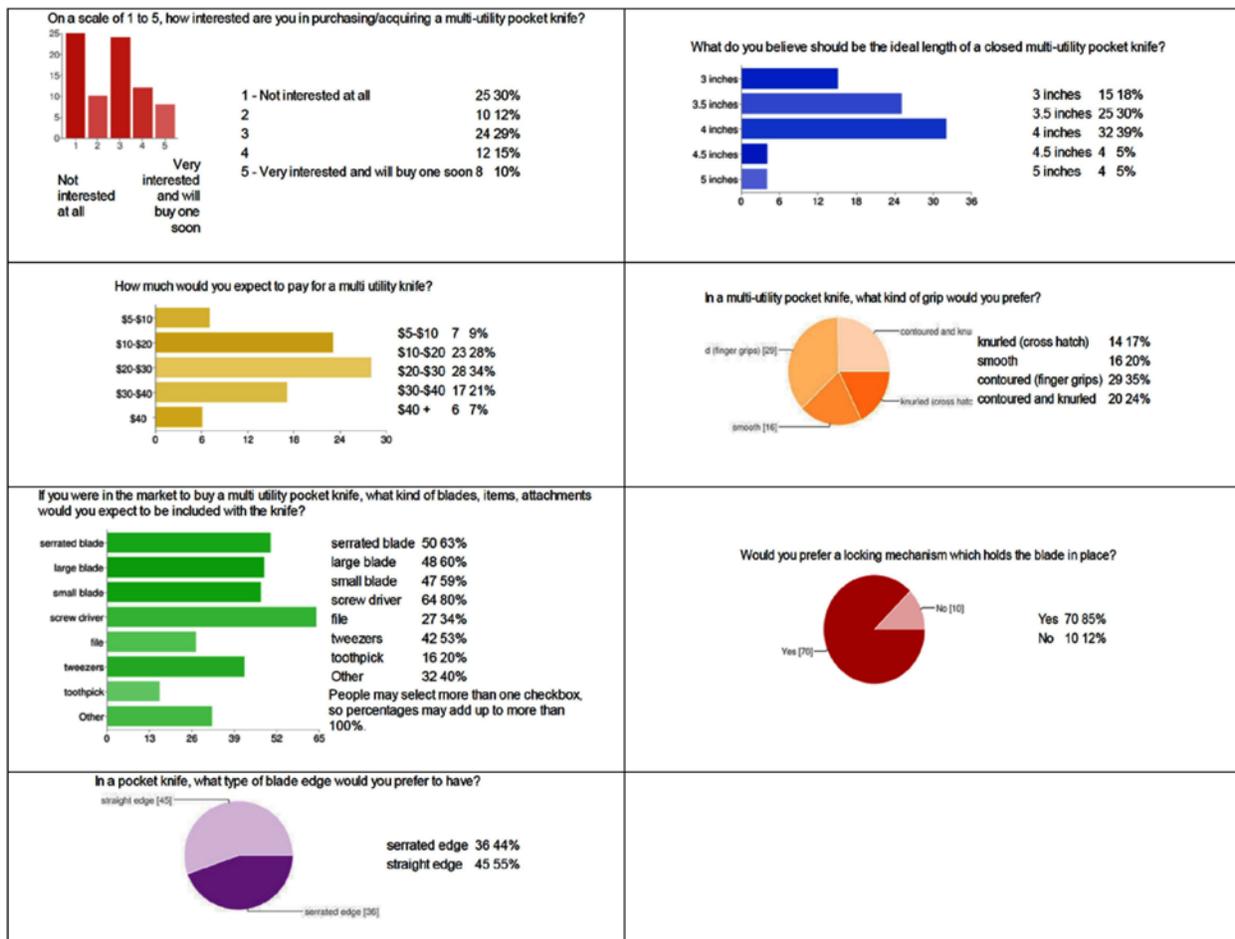
### Preliminary Results

The pilot course offering of ET615-Rapid Prototyping and Product Design over the last year has provided the authors with an opportunity to gauge the effects of visual, auditory and information interface in learning remote systems. Throughout the 10 week-term, online students at DU spent 10 weeks to get familiar with the topics in rapid prototyping, operations, and product design. The overview of ET615 is shown in Table 1. Figure 1 depicts screen layout of Drexel University online access to ET615-Rapid Prototyping and Product Design course materials website.

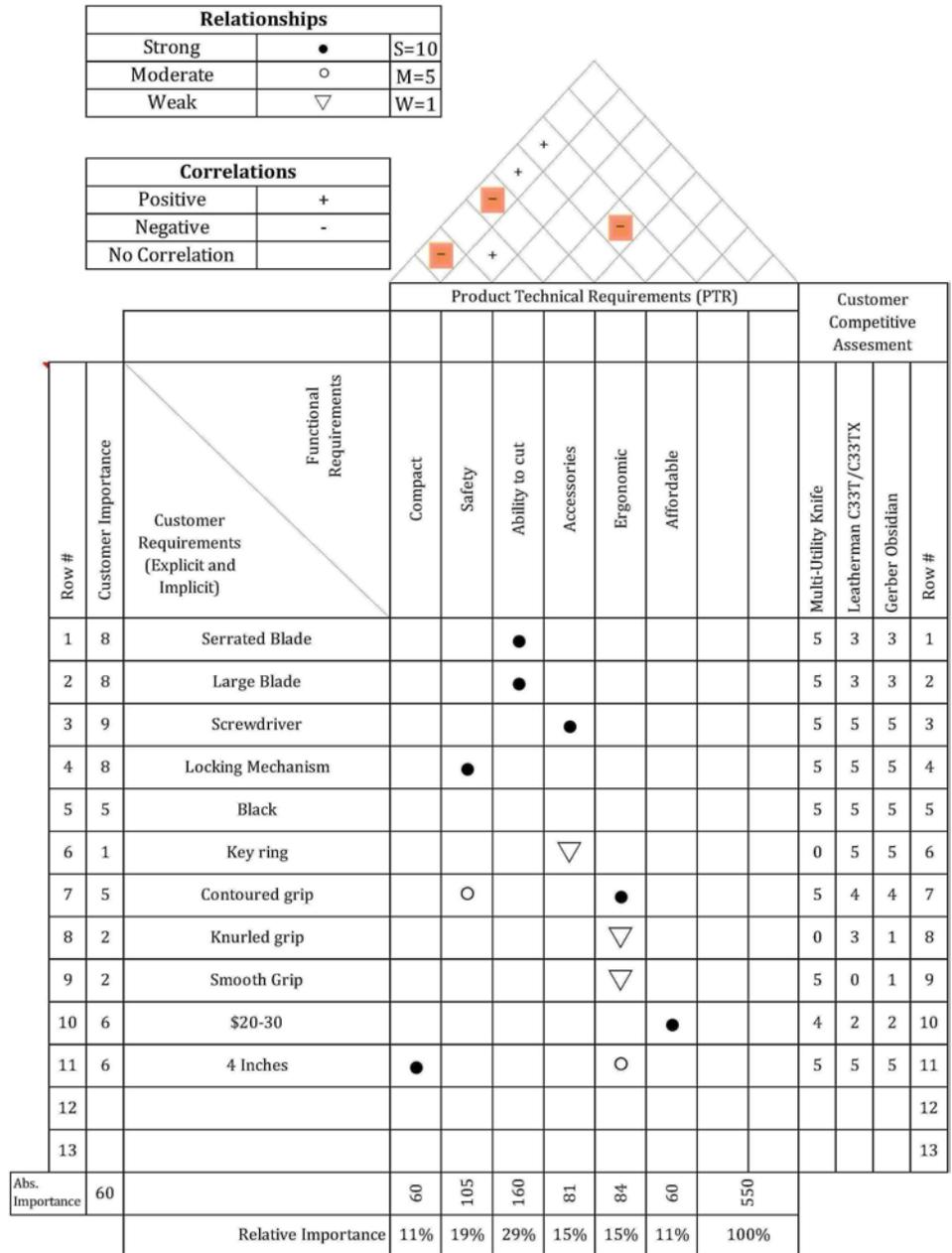


**Figure 1.** Screen view of Drexel University's online access to ET615-Rapid Prototyping and Product Design course materials site.

Each unit is supported by narrated power point presentation, video and process animations as well as weekly assignments and discussions. To aid in improving understanding of Fused Deposition Modeling which is one of the widely used rapid prototyping technology in the product development field, a series of videos (Figure 5) were developed in the Mechanical Laboratory of Engineering Technology department using Stratasys® uPrint 3D Rapid Prototyping machine. In addition, as a course requirement, online students formed design teams to collaborate on a team design project off campus. This course simulated design, analysis and prototyping cycle currently used in product design and development<sup>5, 6, 9, 12, 13</sup>. Student teams of two had to come up with the product design specifications. To do this efficiently, students had to find what the customers (Voice of Customer-VOC) want from their designed products; therefore they had to survey potential customers, friends, family members, etc. One of the survey responses to online survey developed by the student team is provided in Figure 2. Based on VOC data, student design team developed a Quality Function Deployment (QFD) chart to determine technical requirements of the design, i.e. product design specifications. A sample Quality Function Deployment diagram developed by student design team is given in Figure 3.



**Figure 2.** Survey response to online survey questions developed by student design team for utility knife project to find Voice of Customer (VOC)<sup>14</sup>.



**Figure 3.** Quality Function Development (QFD) diagram for utility knife project developed by student team<sup>14</sup>.

At the end of the quarter term, using SolidWorks<sup>®</sup> software<sup>2</sup>, students generated CAD models in STL format and converted CAD models into 3D printer's native format (cmb file format, Figure 4i-j) using Catalyst<sup>®</sup> 3D printing software. Then, using Drexel University's Virtual Private Network (VPN) access, students uploaded necessary part files into a Fused Deposition Modeling (FDM) rapid prototyping machine housed in ET mechanical laboratory (Figure 5). The connection to the Drexel University's (DU) prototyping machine was established by the utilization of Winsock components and various ActiveX controls that communicate through IP addresses. After students uploaded their files for prototyping into the machine queue, FDM

machine was prepared for 3D printing by the laboratory technician who is in charge of setting up and starting the machine for safe operation. The laboratory technician was also responsible for the monitoring of prototyping process for successful completion. This very well simulates rapid prototyping assets owned by technological companies in several locations worldwide. By directing prototyping efforts to locations with available machine time, under-utilized prototyping assets are used more efficiently, therefore prototyping productivity can be tremendously improved<sup>15</sup>. In an actual industrial setting, rapid prototyping machines are supervised by operator technicians. After finishing and cleaning process, prototype models were mailed to students. Please see Figure 4 for examples of student design projects. Prior to finishing the course, students filled out evaluation forms using Drexel’s Academic Evaluation, Feedback and Intervention System (AEFIS). Based on this evaluation system the overall course rating was 3.7 out of 4.0 (max. scale). ***The best aspects of this course, as perceived by students can be summarized as follows:*** They were highly satisfied by the opportunity provided by this class to be creative and to use interesting materials and software. Students particularly embraced using SolidWorks® and team project for product design. The course really changed the way that they regarded prototyping and manufacturing. Quoting of several of the student reviews are provided below:

- *“The final project was a huge learning experience and it was an exceptional replacement for a final. This was real world experience that can't be learned from a book.”*
- *“The ability to design a product and then have it actually printed and mailed to us! I can't wait to see my creation!”*
- *For me having to learn solid works, and doing the team project, those were two very hard assignments but well worth the time and effort. I will never look at manufacturing the same!*
- *Overall I thought this was a very good course. The instructor was engaged and interested. The final project was a huge learning experience and was an exceptional replacement for a final. This was real world experience that can't be learned from a book.*

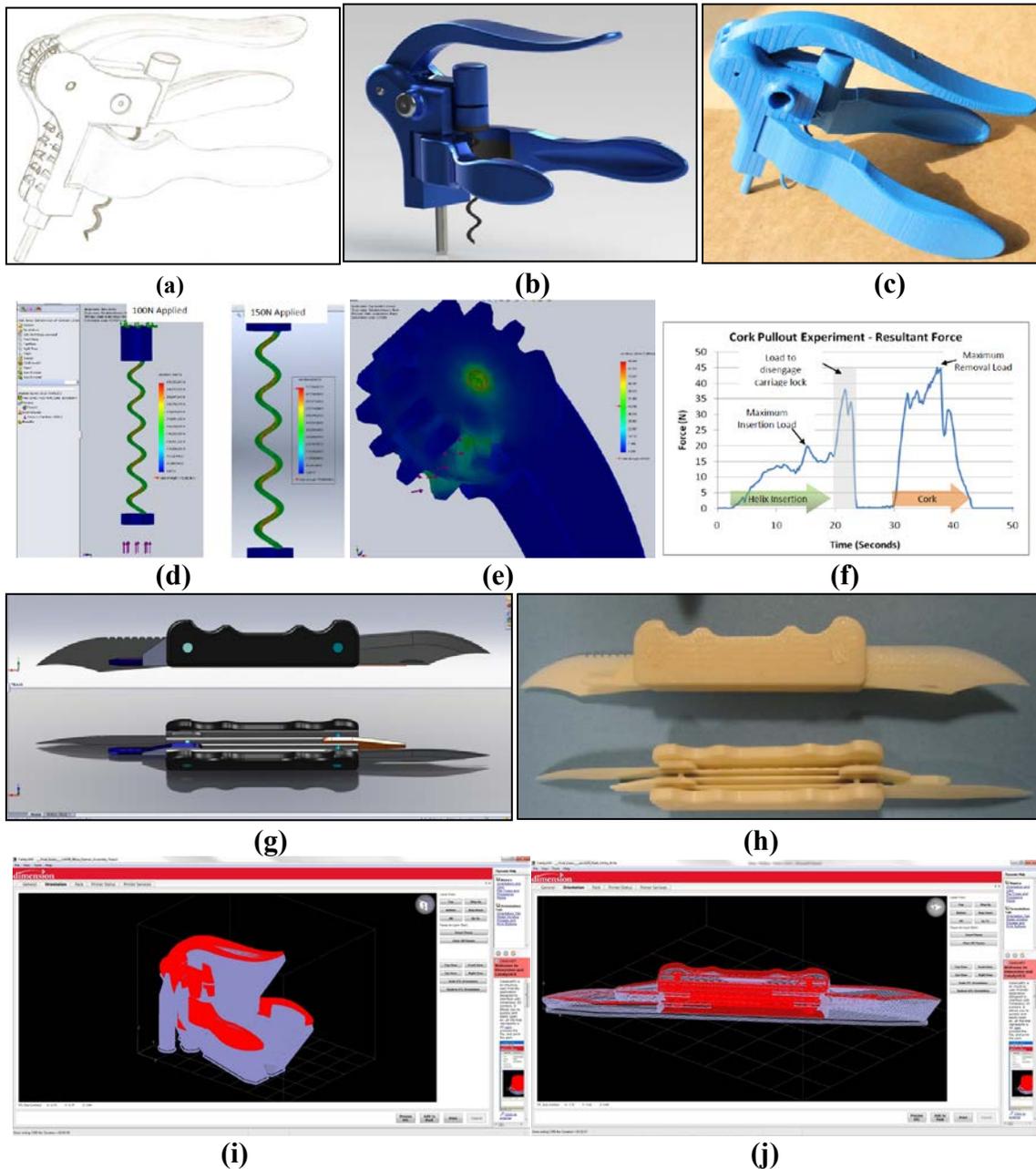
Given these results and in response to students’ feedback, this course will further enhance online laboratory learning through a detailed plan.

**Table 1.** Overview of ET615-Rapid Prototyping and Product Design

<b>Week</b>	<b>Topic</b>
<b>1</b>	Development of a Successful Product, Cost, Quality and Time to Market
<b>2</b>	Product Development, Product Prototyping
<b>3</b>	Prototype Planning and Management, Product and Prototype Cost Estimation
<b>4</b>	Prototype Design Methods, Prototype Design Tools
<b>5</b>	Prototyping Materials and Tools
<b>6</b>	Materials Selection and Structural Modeling, Geometric Modeling and Virtual Prototyping
<b>7</b>	Geometric Modeling and Virtual Prototyping with SolidWorks® I Geometric Modeling and Virtual Prototyping with SolidWorks® II
<b>8</b>	Rapid Prototyping Overview, Rapid Prototyping Procedures
<b>9</b>	Liquid-Based RP Processes-SLA, SGC, Solid-Based RP Processes-FDM, LOM
<b>10</b>	Powder-Based RP Processes

**Table 2.** Course objectives for ET615-Rapid Prototyping and Product Design

1	To provide competence with a set of tools and methods for product design and development.
2	To provide confidence in your own abilities to create a new product.
3	To provide product development experience using Computer Aided Design (CAD)-Mechanical Design tools.
4	To provide an overview of current product and prototype development issues.
5	To provide a guideline and necessary tools for rapid product realization and prototyping.



**Figure 4.** Samples of student term project of a consumer product development. (a) Concept sketch (b & g) SolidWorks® CAD modeling (d & e) SolidWorks® Finite Element Analysis

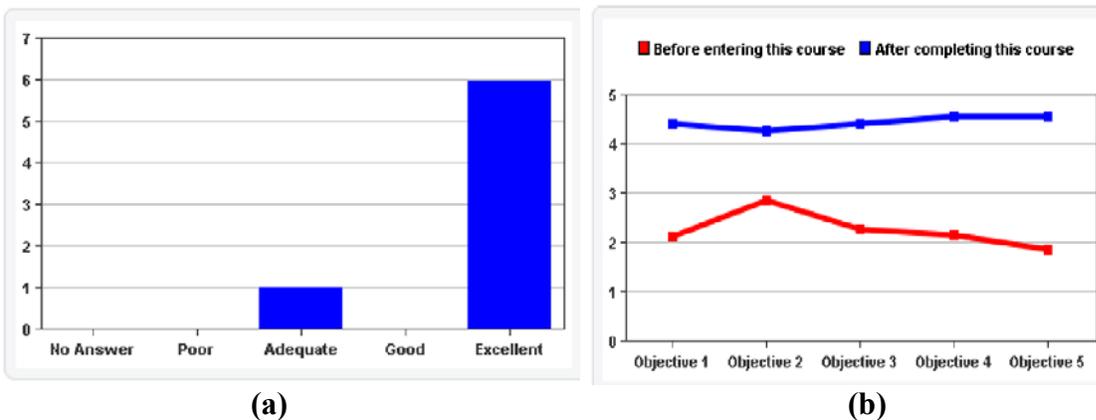
(FEA) Simulation results for Factor of Safety checks (f) Cork pullout experiment for determining load magnitudes (c & h) Prototypes made using Fused Deposition Modeling Rapid Prototyping Machine at DU. (i & j) Catalyst<sup>®</sup> 3D printing software.



**Figure 5.** The Stratasys<sup>®</sup> uPrint 3D Rapid Prototyping machine used for printing student term projects and rapid prototyping demonstration videos developed in-house by ET students.

### Conclusion and Future Work

Students in the Master of Science in Engineering Technology program are required to complete a Rapid Prototyping and Product Design course ET 615. During the survey period, only seven students out of 11 responded to survey questions. The recent course evaluation indicates (Figure 6) that students felt that the course objectives were successfully attained at the end of the term. Students' comments also indicate that term project involving developing a new product and obtaining a physical prototype enhances their understanding of the concepts that are covered through the course. The only significant recommendation we received from students is that to start the SolidWorks<sup>®</sup> component earlier instead of waiting until seventh week. Software installation at student home machine will be done prior to first week of the term. For students that had no experience with this type of design software, the learning curve is generally quite steep. Weekly SolidWorks<sup>®</sup> assignments are being added to the homework schedule to improve student learning of the design software during next offering. These assignments are not necessary to be complex but it will allow individuals to learn the software at a much more realistic pace. The course effectively integrates the contemporary advanced design and manufacturing technologies such as solid modeling, CAE, rapid prototyping, and rapid tooling in improving the product design, analysis, prototype, and production processes.



**Figure 6.** Course evaluation results from Drexel's Academic Evaluation, Feedback and Intervention System (AEFIS) by 7 students: (a) Overall course rating (b) Graph indicates student response to

question: Please rate your perceived performance or understanding of the following course objectives, according the scale provided. 1 = No Understanding - 5 = Complete Understanding

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