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Augmenting a First-year Design Course with an Undergraduate Student Administered SolidWorks Module

Dr. Richard Whalen, Northeastern University

Richard Whalen received his Ph.D. from Northeastern University in Mechanical Engineering. Over the past decade he has been a member of the Northeastern University's Gateway Team. This is a team of teaching faculty devoted to the development and enhancement of the first-year General Engineering program at Northeastern. The focus of this team is to provide a consistent, comprehensive, and constructive educational experience in engineering that endorses the student-centered and professionally-oriented mission of Northeastern University. In addition to the first-year focus he teaches courses in the Mechanical Engineering Department at Northeastern and has won multiple Outstanding Teaching Awards over the years.

Mr. Chirag Patel
Mr. David Joseph Tortoriello
Mr. Justin Baldacci, ASME Northeastern chapter

Justin Baldacci began working on his B.S. in mechanical engineering at Drexel University in 2008 before transfering to Northeastern University in 2010. He has completed two coops during his time at Northeastern University. The first coop position was a facility mechanic at a data center in Boston called Markley Group. The second coop was a manufacturing engineering job at GE Energy in Billerica mass where he utilized Solidworks on a daily basis in tandem with an in house 3D printer. He has been on the ASME club board of officers for three years and is currently working in his third coop as a systems engineer at a heart pump manufacturer called Abiomed.

Mr. Jeffrey Speroni

Speroni is a 4th year Mechanical Engineering student minoring in Mathematics at Northeastern University in Boston, Mass. Speroni has served as the ASME student chapter president, and was a leader in organizing and managing the student run SolidWorks class. Speroni has completed two co-op opportunities while at Northeastern, and is currently in the process of completing his third. His first co-op was at Raytheon Integrated Defense Systems, where Speroni worked as a radar systems analyst. This work experience was heavy on MATLAB and data analysis. His second co-op was at Instron, where he worked on several different projects. Speroni worked on testing a new hardness engineering software, as well as designing custom test fixtures. These designs were made using SolidWorks. His current co-op is at Resolute Marine Energy, where he is again using SolidWorks to design hydraulic systems.

Augmenting a First-year Design Course with an Undergraduate Student Administered SolidWorks Module

Introduction

The overall course goals of most first-year engineering design courses are to introduce students to a design process through hands-on learning activities, to gain experience in graphical communication using software such as AutoCAD, SolidWorks or Pro Engineer, and to inspire and instill an appreciation for the engineering profession, its ethics, and practices. At Northeastern University where experiential education is at the forefront of learning there is a common first-year curriculum for all majors in engineering. This common first year makes it difficult to provide the student with all the tools needed for their first cooperative educational experience (co-op). Students enter the workforce for the first time after they have completed either three or four semesters of classes. Since it is unrealistic to teach to every major the industry specific skill sets required for the introductory jobs, our sophomores occasionally lack in some of the skills and practical knowledge commonly used at the co-op partner firms. One such area that at times arises is in the area of graphical communication. In the first-year design course at Northeastern University, the engineering students are provided with 4 hours of classroom training in each AutoCAD and SolidWorks over the course of a 14 week semester. This 8 hour classroom component turns out to be an adequate amount of time for the electrical or chemical engineering major whose first co-op will typically not require the use of these software packages. However, this is often not the case for the mechanical engineering major where many of our co-op partners will require facility in the use SolidWorks or a similar package. With only a basic working knowledge after 4 class hours, sophomores will often have to self-teach to acquire the more advanced skills necessary to solve the problems presented to them. Additionally, these students often lack understanding of the design-manufacturing relationship, a critical component when transitioning from a digital platform to a physical part. With the benefits of co-op well documented to improve retention by connecting theory to practice, decreasing job search time and increasing starting salaries, it is imperative to adequately prepare our students and give them an opportunity to improve in areas of weakness.[1,2,10]

The upper-class members of the student chapter of the American Society of Mechanical Engineers (ASME) at Northeastern University saw an opportunity to provide a service to the sophomore chapter members who had only 4 hours of SolidWorks instruction. Driven by their past co-op experiences, they developed an extra-curricular course designed to supplement the first-year course and help with the transition of our mechanical engineering students into their first co-op. An added benefit of this course supplement for the upper-class students is first-hand experience in engineering education. Additionally, as we all know, teaching the material leads to a more thorough understanding of the subject matter. [15]

The course allows the upper-class students to use the software as a tool to teach mechanical design principles while in parallel expanding the sophomore engineering students computer aided design skills. Some of the features of the course are: to expand awareness in modeling creation so that they can be easily adjusted and revised, augment discussion of the limitations of different manufacturing techniques and to enhance different styles of communication skills such as technical drawings, hand sketching, and renderings.

The objectives of this paper are to outline the learning activities designed for the student driven course and to provide assessment information on the course's effectiveness. It will also present details and insights for administering these learning experiences for those who may consider using undergraduate teaching assistants to supplement a course.

Background

At Northeastern University, the first-year engineering curriculum is common for all majors and the general engineering courses each year typically have about 25 separate sections of approximately 30 students each. The College of Engineering requires an Engineering Design course during the entering semester in which learning principles of engineering and design is accomplished through active learning in areas such as needs assessment and problem formulation, abstraction and synthesis, implementation, and report writing and presentations in relation to projects that students produce in teams. There is a strong emphasis on applying technical knowledge and developing problem-solving and decision-making skills. In the second semester of the first year, students take a Problem Solving and Computations course that is focused on algorithmic thinking and the solutions to real-life problems using software tools such as Mathworks' Matlab and the C++ programming language. Here problems are derived across all majors. In addition students will take a complement of Math, Physics and Chemistry courses in preparation for their first co-op.

Engineering and Design. One third of the class contact time of the Engineering and Design course is dedicated to the objectives of developing and apply drawing and sketching skills and to communicate design and engineering information graphically. Students learn and practice technical drawing and engineering graphics communication using AutoCAD and SolidWorks. As with any common first-year curriculum there must be tradeoffs in what can be taught as major specific in a general engineering course due to time constraints. Ours is no different in this regard as those in the Mechanical Engineering Department would like the focus of the graphical communications component of the first year design course to be in the use of SolidWorks; while those in the Civil Engineering Department would prefer the focus to be AutoCAD. The primary difference is due in part by a direct influence of our co-op partners in each major. A first co-op in Civil Engineering will require a working knowledge in AutoCAD while SolidWorks is required for the Mechanical Engineer. After some discussion a compromise was reached and now both software's are taught. The result is that students now have approximately 8 and 2 hours total of teaching and assessing time respectively in one of the college's computer classrooms with access to the software. This model has the advantage of exposing the student to more than one engineering tool but with the drawback of not being able to cover as much material in each, resulting in less facility.

While exposure to the software is adequate for the purpose of an introduction, the onus is then on the student to invest additional time to gain the necessary facility required for their first co-op position.

AutoCAD. In the General Engineering and Design course AutoCAD is introduced first with the emphasis on 2-D graphical communication and orthographical projections. Students will use the basic draw and modify features of AutoCAD as well as practice creating templates, layers and multi-view drawings. Upon completion of assessment in the form of multiple drawing sets for homework and a 1 hour in class quiz, students are transitioned into 3-D modeling using the SolidWorks software.

SolidWorks. SolidWorks and the use of other 3-D modelers are now widely used in undergraduate programs and are typically introduced in the first-year then used in subsequent years in the mechanical engineering curiculm.[4,5,7,13] At Northeastern University the SolidWorks component is managed in much the same way as the AutoCAD component. Students will practice creating simple 3-D models using many of the same simple sketch and modify tools presented in AutoCAD. Commands include: Line, Circle, Arcs, Rectangle, Splines, Offset, Fillet, Chamfer, Trim, Mirror, Move, Rotate, Copy, Scale, Stretch, Array Copy (Linear or Circular Sketch Pattern), Text/ Leader/Dimensioning and Layout Commands. Basic Features commands include: Extrude, Extrude Cut, Loft, Revolve, Draft and Hole Wizard. By the end of the 4 hours of lab instruction students are able to build simple parts and assemblies, create the corresponding drawing files and even conduct straightforward motion studies.

Undergraduate Teaching Assistants. The use of undergraduates as teaching assistance to support classroom activities is becoming more prevalent as many programs struggle with enrollment, finances and retention or have no graduate student pool to draw from.[8,9,14] In many cases students, such as juniors or seniors, typically have the knowledge base in their respective majors to effectively assist students with core course material and are often seen as more approachable than their engineering professors.[16] In addition, they have a fresh exposure to the course content and the energy and excitement for their major -making them an ideal conduit to promote the benefits and provide advice for the challenges that await them as they progress through their academic career.[11] The upper class students used in teaching the SolidWorks module all have industry experience using the software from co-op and in some cases have taken an upper level course in manufacturing that utilizes the software.

To prepare for the teaching experience, the pool of students drawn from the ASME chapter at Northeastern University consulted with the ASME faculty advisor to review the tutorial material and teaching strategies. The class is tutorial driven with a facilitator showing modeling steps to the students via a projection screen in a typical classroom set up with computer workstations. Other undergraduate teaching assistants are in the room roaming to help students struggling with the steps and concepts. This approach requires each student to be fluent in the software but not necessarily with more traditional teaching concerns such as accommodating varying learning styles or assessment strategies thus limiting the amount of training time required to successfully implement the course module. For each of the lab sessions a minimum of 4 undergraduate teaching assistants was utilized in a computer room with space for a maximum of 34 students.

Course Description

The SolidWorks module is tutorial driven and designed to be projects based around each of the learning modules. Evaluations of project-based courses show increases in student motivation, problem-solving ability, communication and teaming skills, knowledge retention, and capacity for self-directed learning.[12] Each of the course modules is designed to augment the 4 one hour classes presented in the Engineering and Design course. The topics presented in the original course consist of the following: Getting Started and Sketch Entity Tools, More on SolidWorks Features, Orthographic Views, Dimensions and Drawing Files, and finally Assemblies and Motion Studies. The level of detail each student receives will vary due to the number of instructors and their competency in the software. The augmented course is designed to review these basic elements and introduce new topics routinely seen on a first co-op experience. Five 2 hour modules were created for the augmented course. Each module description that follows discusses the details of what was implemented along with the undergraduate teaching assistant observations, anecdotes and relations to a first co-op experience.

Module One. The first module of the course began with preliminary student assessment to gage the current level of knowledge of those enrolled followed by instructions that laid a foundation for the rest of the course. The results of the assessment will be described in the assessment section of the paper and used approximately 45 minutes of the two hour class. The instructors then used about one hour to speak about the different topics and demonstrate them using the computer and projector. Due to the large amount of information, the instructors decided that some lecture would be necessary in order to convey all of the information of this first module. The final 15 minutes was used for an in-class activity to practice topics discussed during the class.

The first topic in the module is to further develop technical drawing skills since time constraints do not allow the first-year curriculum to sufficiently stress the importance or specifics involved. While creating a technical drawing is seemingly less exciting than modeling a three dimensional part, the instructors used this first class to explain that the ability to create a proper technical drawing was often far more valuable to employers than the ability to create a three dimensional model. In this lecture, the topics covered included examples of proper and improper drawing techniques, adding tolerances, notes and annotations, and hole callouts. To help students to understand and remember some of these topics, electronic copies of different reference material were distributed via email. These handouts covered fits, geometric dimensioning and tolerances.

After lecturing on the importance of drawings and some of the proper techniques for making these drawings, the students were asked to create a drawing of a part supplied by the instructors that is shown in Figure 1a. Students were allowed to ask questions and get immediate feedback while making their drawings. The students that did not finish their drawings within the class time were asked to finish the drawings on their own time before the next class.

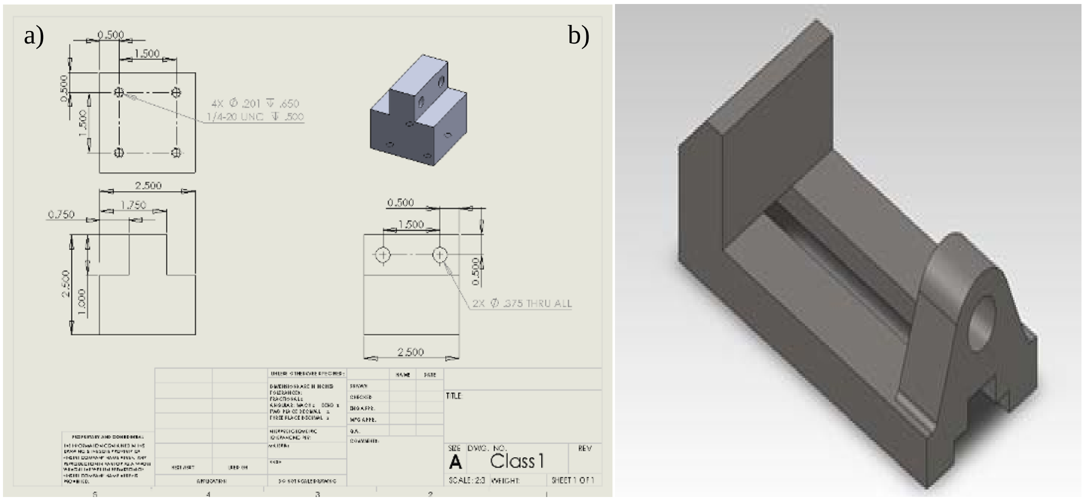

Figure 1. Module One a) in-class assignment drawing and b) homework drawing.

In addition, to further practice and strengthen the skills and methods covered during the first class, students were asked to complete a homework assignment (shown in Figure 1b) before class the following week. This gave the students an opportunity to practice making drawings and receive individual feedback at the beginning of the second class.

From the instructors' point of view, it was difficult to keep the students interested in the material during the hour-long lecture and demonstration. Due to the starting time of the class at 6 PM it was determined that even more interaction and participation during the lecture would be necessary to keep the students engaged. Modifications such as doing a short demo with students trying it concurrently were determined to be the most effective approach. Despite the observed lack of interest and excitement with lecture at times, the instructors believe it is necessary in order to communicate a vast amount of information in a short period of time.

Module Two. The second module began with a brief lecture about the importance and benefits of hand sketching when beginning a first co-op experience. Hand sketching is a vital skill necessary when trying to communicate during initial design discussions. If a co-op can communicate their ideas with this simple skill, they are more likely to be trusted with the creation of the CAD model.

The instructors then moved on to modeling concepts in SolidWorks. The idea and practice of modeling parts the way they will be machined is a common industry standard to control the method in which models are created. In addition, an introduction to taps, threads, and types of holes was given with demonstrations using the Hole Wizard tool in SolidWorks. This is deemed a critical skill because it allows for quick changes to be made to features and automatically creates industry standard hole callouts on the technical drawings that were discussed in the first class. A quick lesson on the differences between the naming conventions of SI and US Customary hardware was also included with this lecture and was very well received by the class.

The final topic covered in the introduction of module 2 lecture was linear and circular sketch patterns. The use of these patterns was discussed and examples of instances in which to use them were provided. All of these topics are directly related to the vast majority of mechanical engineering co-ops available to the students as experienced by the upper-class students of ASME.

Next students were introduced to the Revolve, and Revolve Cut features. These features are used to model axi-symmetric parts that would be machined on a lathe. During this lesson, instructors discussed the different approaches to creating these models and the benefits of the different practices.

After discussing Revolve students were shown how to use reference geometry. That is, axis's and planes that are positioned with relationships to geometry that the user has already created. An example of adding Reference Geometry in order to place a hole on a non-planar surface was shown.

The final lesson within this module included Smart Dimensioning and Sketch Relations. These features are very important when dealing with a new design that will very likely change in the near future. Relations in particular allow the user to have one part or line of the sketch to have control over other features or lines.

This module featured an in-class activity in which the students were instructed to model a part that used the Revolve and Revolve Cut features, and also needed the addition of Reference Geometry. For a homework assignment, the students were asked to finish the in-class assignment, model a pulley (drawing provided), and experiment with radial patterns on an automobile rim. For the final part of the homework, students were given a base model of a blank rim to save time. These parts are shown in Figure 2.

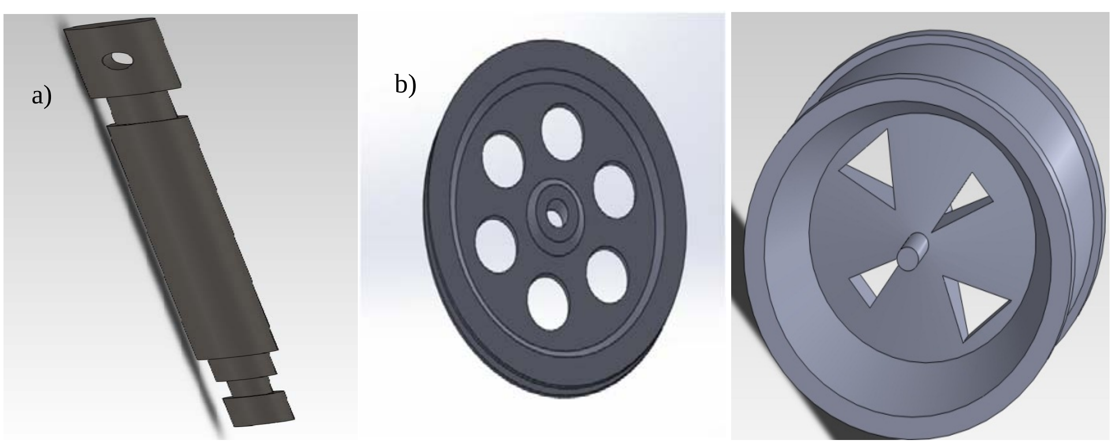

Figure 2. Module Two a) in-class revolve exercise and b) homework assignment drawings.

As for the timing of each component of the module approximately 30 minutes was used for the introductory topics of sketching and modeling concepts. About 15 minutes was needed for the Hole Wizard review since many students were exposed to this in the first-year curriculum. The Revolve and Revolve Cut review lasted about 30 minutes. Only 15 minutes each was necessary to cover reference geometry and relations thus leaving the last 15 minutes for the in-class assignment.

In this class, tutorials were handed out before class for students to use as a resource during each lesson. Anecdotally, the instructors believe that this was actually counterproductive as some students stepped ahead in the tutorial and occasionally made mistakes that had to be corrected with the help of an instructor thus limiting their time with other students. Overall, the second class was better received as there were more activities in which students were working directly in SolidWorks.

Module Three. This was a significantly more challenging than the previous two classes. It required the students to gain a strong understanding of sheet metal, lofts and shelling. The class was split up into two sections. The first was the sheet metal tutorial, and the second was the loft/shelling tutorial in which instructors guided the students through a step by step build of a plastic headphone shell.

The sheet metal portion of the class took up a relatively small amount of time, approximately 30 minutes. Sheet metal is an important feature to learn for SolidWorks because there are many co-op positions that require the design of basic sheet metal components such as various brackets and test fixtures. It was important to teach the students the correct sheet metal etiquette with respect to SolidWorks and this was accomplished via the tutorial part and homework as shown in Figure 3.   There are many ways sheet metal parts can be modeled in SOLIDWORKS that simply cannot be manufactured if one is not careful in the layout of the part. In class examples such as having three planes meet at a corner were used to demonstrate these points. The instructors felt confident that the students would be prepared for the sheet metal requirements they encountered on co-op with only one short tutorial. Any more advanced skills needed could be acquired on the job.

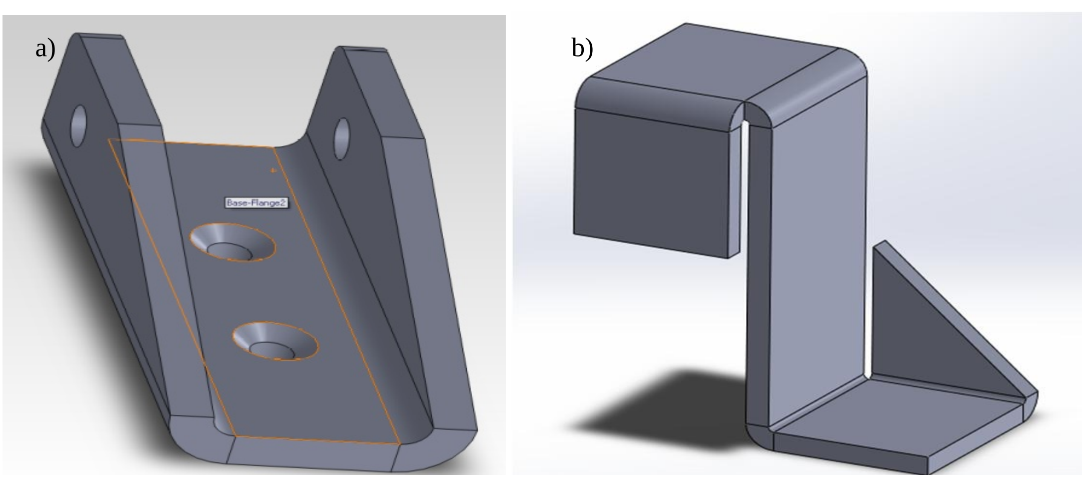

Figure 3. Module Three a) in-class sheet metal part and b) homework sheet metal part.

The remainder of the module (1.5 hours) was dedicated to the creation of a plastic headphone shell and working with Loft and Shell as shown in Figure 4. In the headphone example the students were guided by the instructor through a 17 step process. This was an interesting part because it required the use of lofts and 3D sketching. The students were taught how to create these complex shapes and in a world that is increasingly relying on 3D printing, complex shapes are becoming more and more widely accepted. In addition, several of the undergrad instructors were required to use 3D printers and rapid prototyping on their co-ops and realized that the need for familiarity with these advanced tools is becoming increasingly important in the professional engineering world.

The instructors in module three reverted back to handing out homework and tutorial material at the end of class and this seemed to work out better as no student was moving ahead of the instructor demonstrating the features.

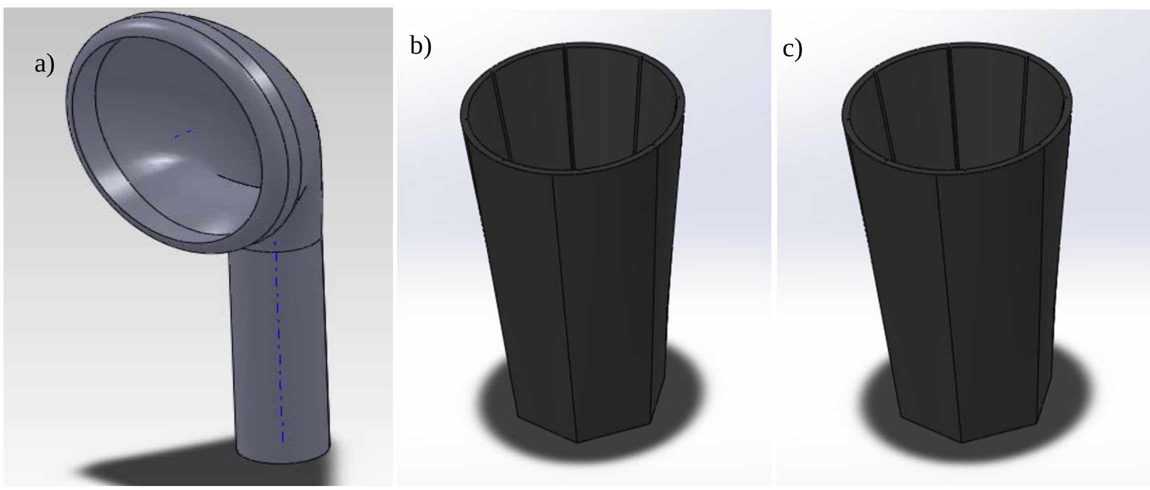

Figure 4. Module Three a) headphone shell tutorial, b) loft and c) sweep tutorials.

Module Four. This module reviewed assembly drawings which are taught in the first-year curriculum and is an exceedingly important aspect of any technical drawing. The module was comprised of an hour long instructor led tutorial focusing on the assembly "mate" features in SolidWorks, while the second half of the class was focused on letting the students assemble a pocket knife that the instructors had shown. The final 10 minutes of the class taught the students how to create an exploded view video for the assembly. This is an especially useful presentation tool when one is trying to show someone how every component of an assembly fits in with the rest of the device and is something typically expected of by co-op employers. The details of the pocket knife assembly are shown in Figure 5a. It is comprised of a 9 piece assembly and the in-class procedure was to have the instructor guide the students through the process of "mating" the pieces together based on their geometric qualities and their actual points of contact in the assembly. The students were then shown a picture of a pocket knife, given several separate parts, and then asked to assemble the knife on their own. This was a good exercise of self ability because the students were given minimal help and as a result were forced to troubleshoot their way through the assembly.

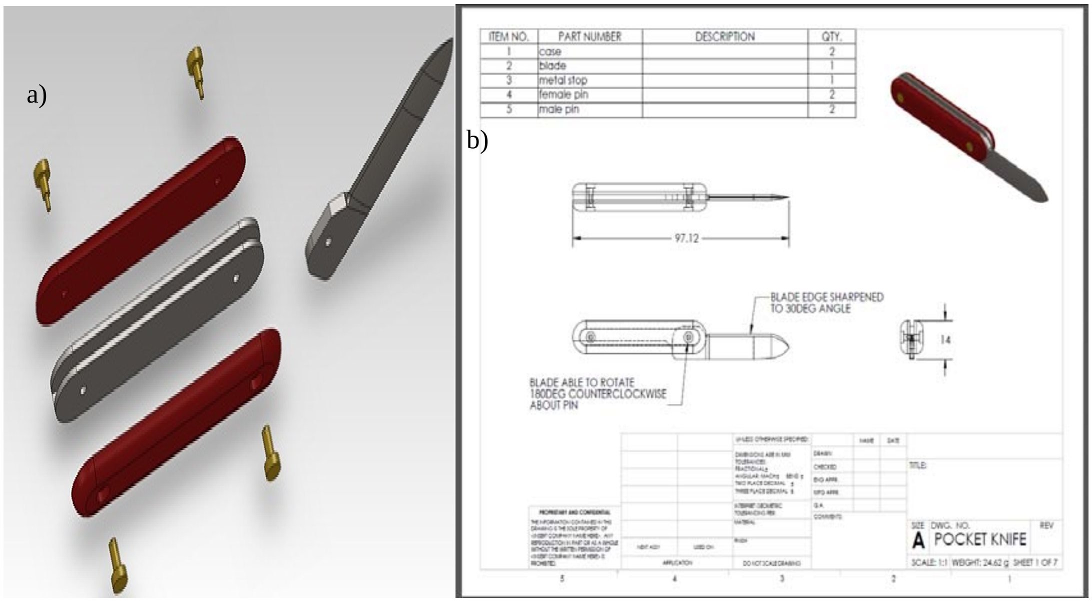

Figure 5. Module Four a) in-class pocket knife assembly tutorial and b) drawing file tutorial.

Once the student finished the assembly the instructor then showed them how to create an Assembly Drawing file complete with a Bill of Materials (BOM) as shown in Figure 5b. The instructors highlighted how essential it was to balloon callout each part so someone could easily identify where they resided in the assembly. Finally the students were shown how to create an exploded view movie which would start with the assembly completely fitted together, then pull out each part and proceed to push the parts back into the assembly. This is a useful presentation tool for anyone who is showing off an assembly at a meeting or conference and most of the instructors were tasked to do this on their first co-op.

Module Five. The final class featured an advancement of some of the topics found in the previous lessons in addition to short lessons on a number of other features and tools that SolidWorks contains. The first 30 minutes of the module was a lesson on Advanced and Mechanical Mates. Advanced and Mechanical Mates are used to have assemblies behave in more realistic ways. These mates are useful to help a proof of concept or simply have a more authentic CAD model. For example, Advanced Mates can add stopping points to an assembly to avoid parts “floating” through each other. An in-class activity was used to help students practice using these advanced mates using the vise drawing shown in Figure 6. Here the instructors walked the students through a tutorial that described how to accomplish the transformation of standard mates into advanced mates to limit the vise travel.

The lesson continued using the next 30 minutes of the module on the creation of technical drawings of assemblies included the addition of a Bill of Materials (BOM) as discussed in module 4, creating an exploded view, and adding those items into a drawing file. This section also included a short lesson using Motion Study in which the students were shown how to create an animation that would disassemble, then reassemble the assembly of parts. The emphasis here was to show the students that this is an important tool to use when one needs to show others the way an assembly was made. A second in-class activity was used after this lesson to walk students through the process of creating technical drawings of assemblies again using the pocket knife shown in Figure 5. As discussed previously, creating technical drawings is a critically important skill for mechanical engineering co-ops.

The next topic of the module focused on the limitations of machining, the tools involved with machining and how they relate to using certain features in SolidWorks. Designing parts and systems is considerably more effective when the engineer is educated about manufacturing techniques and any limitations that will be placed on the process planning. In certain instances the use of some SolidWorks features as previously mentioned make a part impossible to manufacturing or at least very difficult. Here a slot with 90 degree angles and extrude cuts on a complicated spline were used to demonstrate. The lesson continued with an introduction to Interference Testing, Mass and Material Properties, Finite Element Analysis (FEA) capabilities and some of the rendering tools found in SolidWorks. These topics were demonstrated by the instructors using 30 minutes of the module.

The final 30 minutes of class was devoted to the final assessments and surveys to evaluate the class and student performance. The students were given a final opportunity to ask questions of the instructors and were reminded they would be available as a resource in the future as they begin their co-op opportunities. From the instructors' point of view, the final class was quite rushed. While all of the topics were covered during the class, there was a vast amount of information that had to be communicated in a reduced class due to the necessary final assessments. Additional time will be arranged for in the future to accommodate the assessment in the next run of the course. Despite this the students seemed to be very interested in the topics covered.

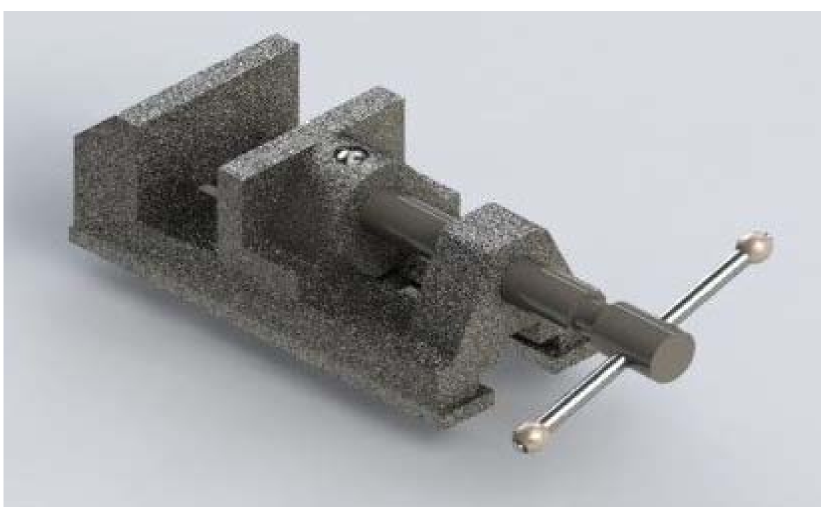

Figure 6. Module Five assembly drawing of a vise.

Methodology and Assessment

A pre and post survey and skills evaluation was deemed essential in order to assess the effectiveness of the material presented and the performance of the undergraduate teaching assistants. The surveys and skills evaluations described below were administered to the class of 32 students taking the 10 hour augmented Solidworks course during the fall semester 2012. The augmented course modules are not part of a credited course and are open to all Mechanical Engineering students of any graduation year. Since SolidWorks was introduced in the Fall of 2010 in the first-year Engineering and Design course, the cohort consisted of not only Sophomores looking to advance their facility in the software but also of upper-class students who did not receive any previous SolidWorks training in the first-year. There were 14 Sophomores, 15 Middlers, 2 Juniors and 1 Senior enrolled in the course with an average GPA of 3.2/4.0. It should be noted that Northeastern University has a 5 year Bachelor of Science program with the additional 5th year called the Middler year. The course modules were implemented by 4 upper-class undergraduate teaching assistants all with at least one co-op experience and fluency in SolidWorks.

Pre-Survey. The students were first surveyed to evaluate their experience and comfort levels with different topics and tools within SolidWorks. In addition, a skills assessment was given to serve as an objective tool to quantify the students' current proficiency. These assessments took about 45 minutes of the first class, 15 minutes for the first survey, and another 30 minutes for the objective skills assessment. The survey is shown in Appendix A.

Post-Survey. After completion of the last module students completed the post-survey and skills assessment to determine the effectiveness of the course. Likert-scale and open-ended questions focused on instructor effectiveness, amount learned, pace of instruction, skills acquired, quality of support materials and tutorials and suggestions to improve implementation. The survey is shown in Appendix B.

Results and Discussion

Pre-Survey Results. Before starting the augmented class, approximately 40% of the students reported "Little" or "Not Familiar With" the basic SolidWorks features of Extrude, Extrude Cut, Chamfer and Fillet and over 60% reported this for Revolve and Hole Wizard as shown in Figure 7. In addition students reported "Little" or "Not Familiar With" just over 80% of the time for the features of Sweep and Loft and 75% for Linear Pattern. These results are not unexpected as 55% of the students are Middlers or above and would not have been exposed to SolidWorks in the first-year Engineering and Design course.

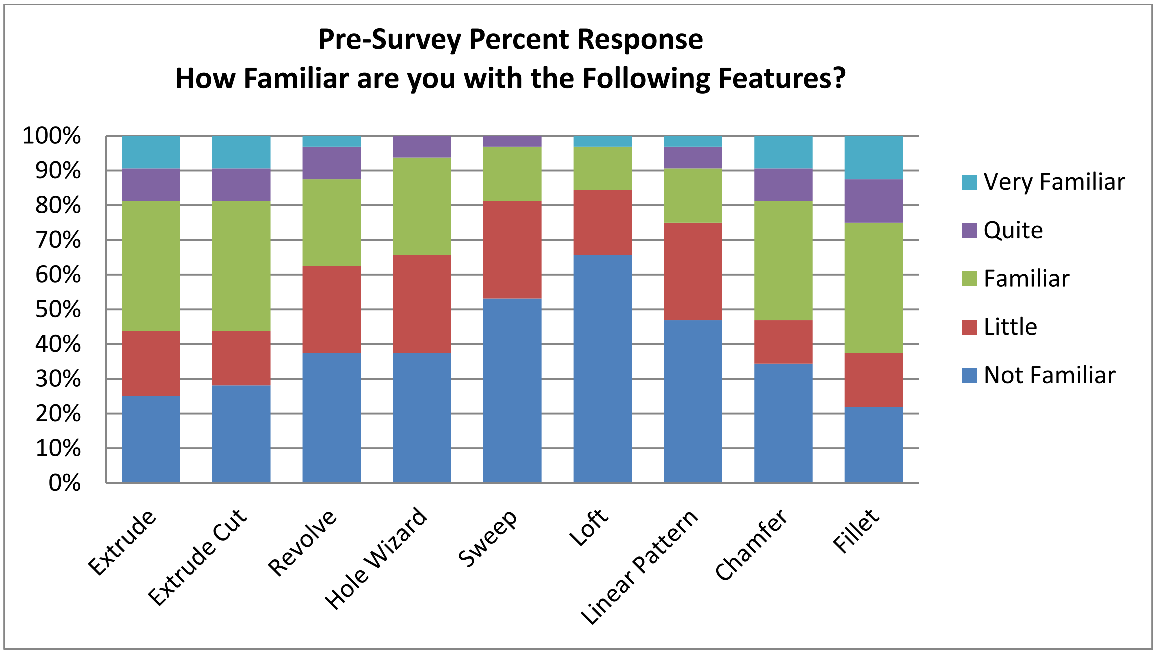

Figure 7. Pre-Survey percent response of student familiarity with basic SolidWorks features.

In regards to advanced SolidWorks skills such as using Mates and Assemblies, Motion Studies, Callouts, Dimensions and Tolerances, and adding a Bill of Material the results again are as expected with students having even less familiarity than with the basic features. Figure 8 reports that approximately 90% of the students responded with "Little" or "Not Familiar With" in the categories of Bill of Material, Notes, Sheet Metal, Callouts and Motion Studies. Approximately 70 % reported this for Mates, 80 % for Tolerances and 52% for Dimensions.

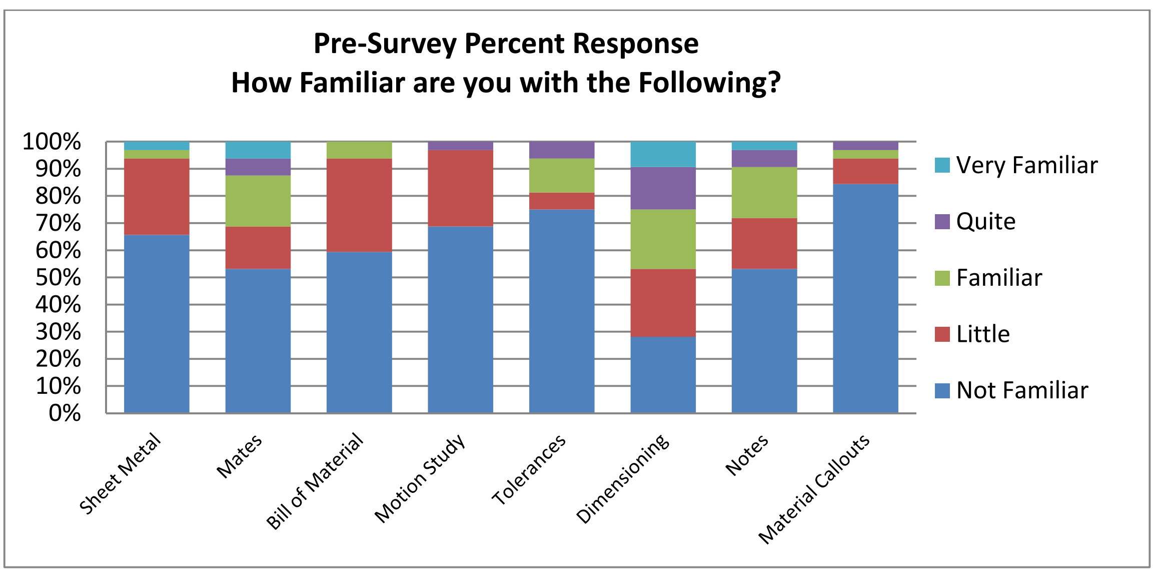

Figure 8. Pre-Survey percent response of student familiarity with advanced SolidWorks features.

Figure 9 reports familiarity with two practical engineering skills related to engineering design, machining and manufacturing techniques. Here students reported with "Little" or "Not Familiar With" in these two categories 70% and 65% of the time respectively. In the first-year program students are not exposed to machining while some instructors will briefly cover manufacturing techniques. In addition most first co-ops will expose a student to manufacturing which might explain the 35% response of "Familiar" and "Very Familiar" in this category.

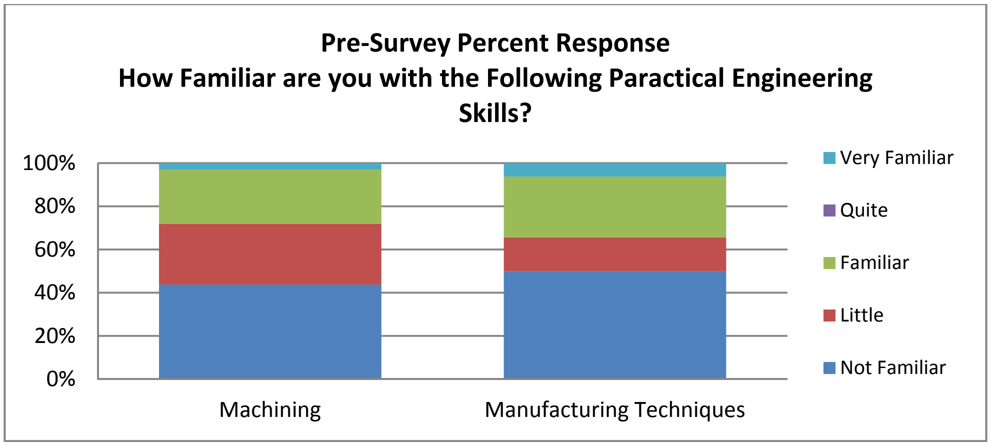

Figure 9. Pre-Survey percent response of student familiarity with practical engineering skills.

The objective skills assessment drawing administered during the first module is shown in Figure 10. This was a timed exercise of 30 minutes and students were assessed on 9 key points; point 1 completing the model and layout, and points 2 through 9 proper hole location, sizing and dimensioning as indicated by the 8 dimensions shown on the drawing file. The overall average score of the assessment was 3.67 out of 9 or a 41/100. The result is not unanticipated after the review of skills presented in Figures 7 and 8 indicate that over half of the cohort has limited facility with the software.

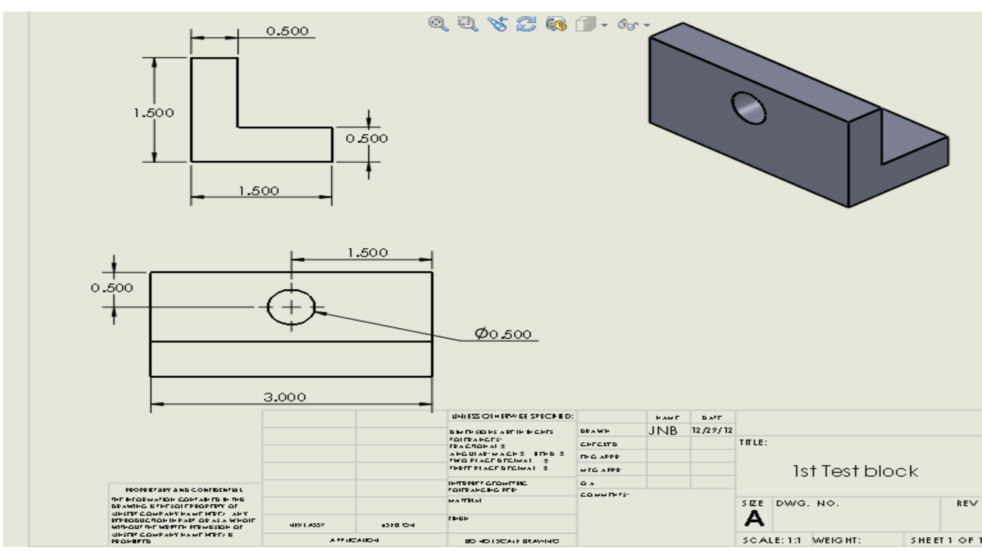

Figure 10. Pre-Module objective skills assessment drawing.

Post-Survey Results. After completion of the last module students completed the post-survey and skills assessment and the results of familiarity with the basic features are shown in Figure 11. For the categories of Extrude and Extrude Cut 87% of the students reported "Very Familiar With" or "Quite Familiar With" whereas these were reported only 20% of the time in the pre-survey. For the modifying commands of Chamfer and Fillet, 67% of the students reported "Very Familiar With" or "Quite Familiar With" which is an increase of 47 and 42 percentage points respectively over the values reported in the pre-survey. Similarly for both Loft and Sweep 40% of the students reported "Very Familiar With" or "Quite Familiar With" post-survey in comparison to only 3% responding in the pre-survey. With Revolve, Hole Wizard and Linear Pattern students responded with "Very Familiar With", "Quite Familiar With" or "Familiar With" approximately 87% of the time while reporting in the pre-survey for the same categories values of 39%, 35% and 26% respectively. It is clear that the students perceive that they have much greater facility in the basic features of SolidWorks post modules which gives us impetus to continue with future iterations.

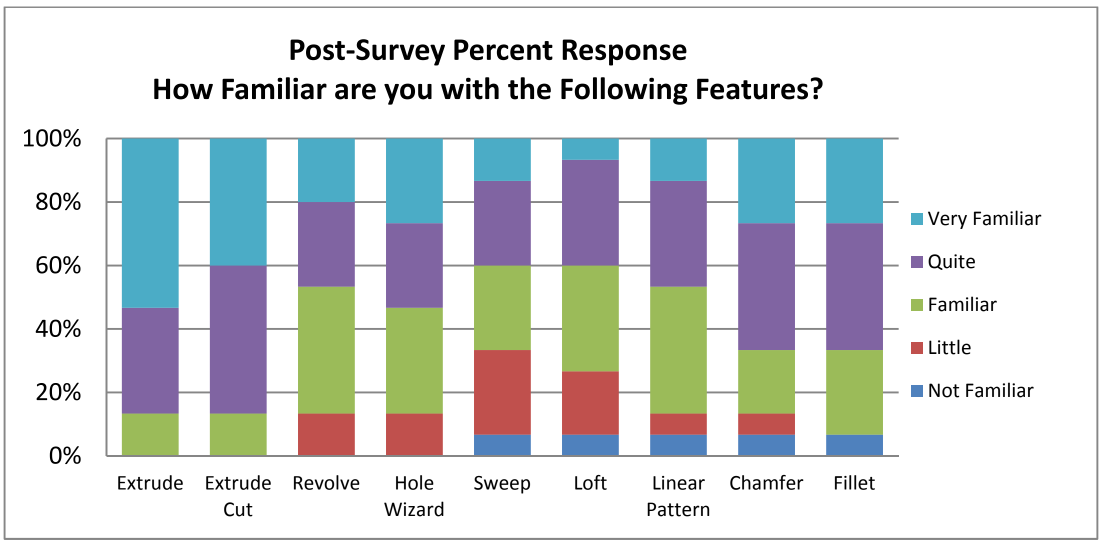

Figure 11. Post-Survey percent response of student familiarity with basic SolidWorks features.

In much the same way as in the basic features, the student's self-assessment showed an increased facility in using the advanced features of SolidWorks as shown in Figure 12. In the categories of Sheet Metal, Bill of Material, Motion Studies and Notes approximately 80% of the students responded with "Very Familiar With", "Quite Familiar With" or "Familiar With" as opposed to in the pre-survey where 90% of the students responding with "Little" or "Not Familiar With" for the same categories. Only 5% of the students now report "Not Familiar With" for Mates whereas 52% reported this in the pre-survey. For Tolerances and Callouts approximately 12% report "Not Familiar With" in the post-survey while these values were 75% and 83% respectively in the pre-survey. Finally in the post-survey all students report at least "Familiar With" for the category of Dimensions, a marked improvement over the pre-survey where 52% responded with "Little" or "Not Familiar With".

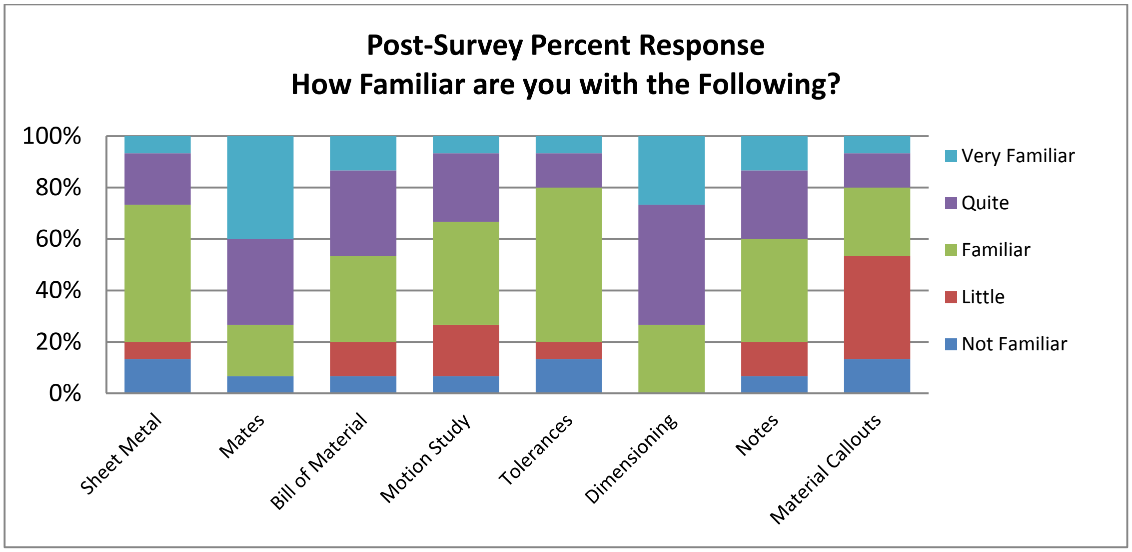

Figure 12. Post-Survey percent response of student familiarity with advanced SolidWorks features.

The previous two figures are student self-evaluations and both show a perceived increase in facility with the software. Figure 13 is the objective skills assessment drawing administered during the last module. Students were given 20 minutes to complete the model and drawing and were assessed on 7 key points. The first 2 points were given for correct modeling of the plunger body and handle, 1 point was given for completing the mating of both parts and 4 points for completing the drawing file with annotations. The overall average score of the assessment was 5.5 out of 7 or 79/100. This is a 48% improvement over the raw pre-module objective skills assessment score. This improvement is made more striking when one considers it does not account for the fact that the students performed better on a drawing made more complex than the pre-module skills assessment -here students mate multiple parts in an assembly and create a drawing file all while being given 10 less minutes than in the pre-module skills assessment survey.

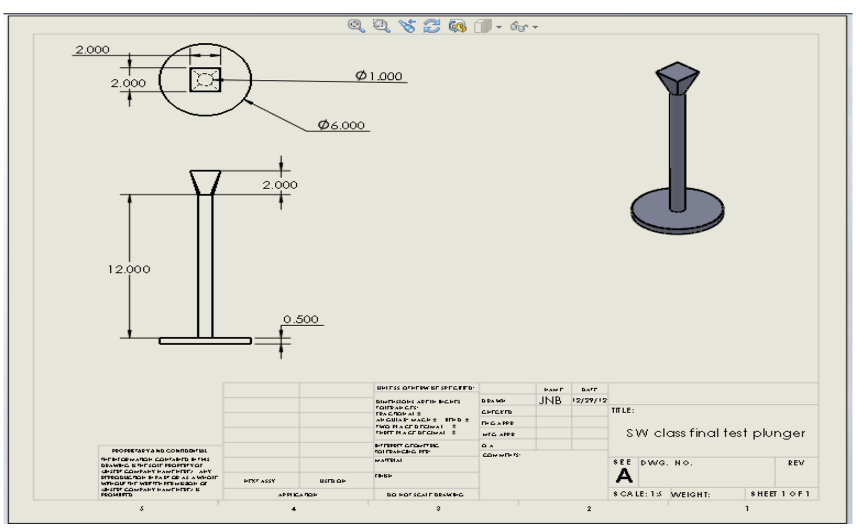

Figure 13. Post-Module objective skills assessment drawing.

Figure 14 reports self-assessment familiarity with the two practical engineering skills related to engineering design; machining and manufacturing techniques. Here again students reported an increase in familiarity with these topics after completing the course modules. In the category of machining students report “Familiar With” or above 75% of the time whereas in the pre-module survey 70% reported “Little” or “Not Familiar With”. The increase is less dramatic for manufacturing techniques due to some familiarity with it as measured in the pre-module survey. They reported “Familiar With” or above 60% of the time whereas in the pre-module survey 65% reported “Little” or “Not Familiar With”.

Bases on the objective skills assessment and the student self-assessment surveys it is apparent that the students have gain facility in the use of SolidWorks and increased their technical drawing skills. The use of undergraduate teaching assistants to administer the material to other students is an acceptable approach in this regard. Their experiences on co-op were incorporated into each lesson and students have now gained valuable insights into the machining and manufacturing techniques used in industry.

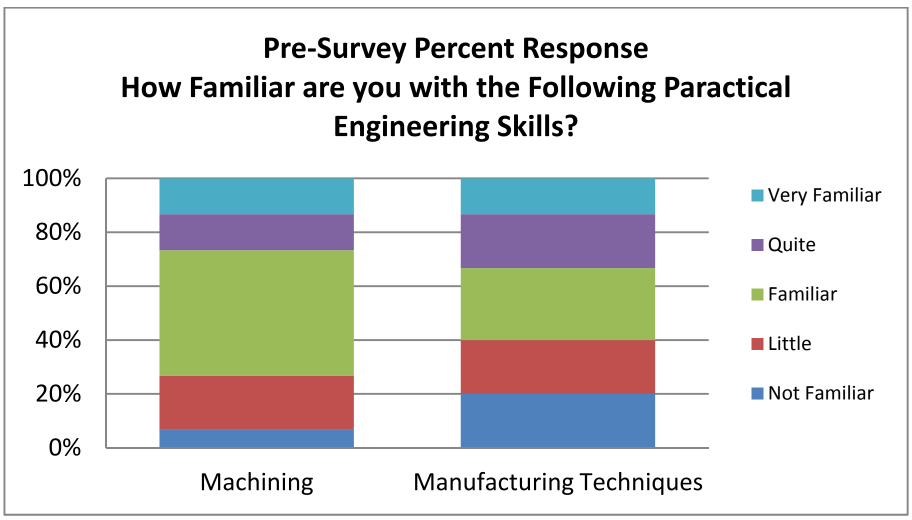

Figure 14. Post-Survey percent response of student familiarity with practical engineering skills.

Course and Instructor Evaluation Results. As at any university, all courses and instructors are formally evaluated by students at the end of the term and we thought it would be best to evaluate the course modules in a similar fashion using Likert type responses. The questions are typical, as found in our surveys, and were modified slightly for this application. Table 1 reports the mean responses using a scale of 1 to 5, where 5 relates to “Strongly Agree” for questions related to amount learned and course value. The highest reported mean response is 4.73 in both “This class improved my SolidWorks knowledge” and “I am glad to have taken this course”. Students are stating not only have they learned and gained facility in SolidWorks but are satisfied with the value received for their investment. In addition with scores of 4.47 and 4.33 in “I learned a lot” and “…I feel more prepared for co-op” the students believe that the major course outcome of learning more about SolidWorks in order to be better prepared for their first co-op has been met.

Table 1. Likert Responses to statements about the course module effectiveness.

Strongly Disagree = 1 → Neutral = 3 → Strongly Agree = 5

Statement	*Mean*
The lectures helped me to learn.	4.53
This class improved my Solidworks knowledge.	4.73
I learned a lot from this class.	4.47
I am glad to have taken this course.	4.73
I have developed additional Solidworks skills, and I now feel more prepared for co-op after taking this class.	4.33

Table 2. Likert Responses to statements about the instructor effectiveness.

Strongly Disagree = 1 → Neutral = 3 → Strongly Agree = 5

Statement	*Mean*
The instructors communicated ideas and information effectively.	4.67
The instructors were effective in teaching this course.	4.73
Having roving assistants helped me learn.	4.80
The class provided sufficient feedback to determine progress.	4.00

Table 2 summarizes the student response of the instructor evaluation questions. The mean responses for "The instructors communicated ideas and information effectively" and "The instructors were effective in teaching this course" were 4.67 and 4.73 respectively. Students overwhelming agree that the undergraduate teaching assistants were effective in delivering the course content. In addition, they liked having additional roving instructors helping them during the lectures and tutorials and feel that there was sufficient feedback to help them learn. The previous two tables support the use of undergraduate teaching assistants to facilitate the learning modules developed to meet the needs of this student population.

Conclusions

The learning activities described in this paper, designed for the student driven course, were shown to enhance the facility of undergraduate students in the use of SolidWorks. The following assessment data makes for a strong recommendation to any university considering the use of undergraduate teaching assistants, when properly trained, to augment a course with supplemental modules. Students reported a sense of value, perceived and measured increases in facility in the use of the software, and an overall sense of being more prepared for a first co-op experience in Mechanical Engineering.

When students were asked *"Do you feel you are a more desirable candidate to employers after taking this class and why?"* they commented:

"Yes. I actually got a job because of this class, and was able to negotiate the pay higher because I was taking the class. Thanks"

"Yes, I think I can confidently say in an interview that I'd feel comfortable with a position involving SolidWorks."

"The emphasis on manufacturing was very beneficial. Upon mentioning that to co-op interviewers this semester, they became very interested and where happy to hear about that. Definitely something you should keep doing for a variety of reasons."

"Yes, in fact I'm fairly confident I got my current co-op just because of my entry level knowledge of tolerances."

"Yes, because we learned from students who have been on co-op and done SolidWorks drawings for companies before. Their experience shone through and made everything we did feel relevant and important. Especially the work with drawings and designing for manufacturability."

These comments are important in the sense they will help drive future upper-class members of ASME to continue the service to their fellow students providing them additional access and training to a valuable engineering tool. In addition to and possible more importantly, they are providing first-hand knowledge of what to expect on their first co-op.

In the future, the undergraduate teaching assistants plan to refine and modify the modules bases on the comments received from the assessment. Issues, such as when to handout a tutorial, before or after the module, will be further analyzed as the small sample size resulted in inconclusive data for one way or the other. Some students reported they preferred it before; to prepare for a lecture and use it as a reference during lecture, while other liked it afterwards -so they would pay attention to the lecturer and not be tempted to move ahead. Anecdotally the instructors found it beneficial to hand them out later to avoid the issue of having students become stuck from moving ahead. Finally the ASME student group would like to offer the Certified Solidworks Associate Exam (CSWA). This would be validation and proof of facility with SolidWorks for those completing the modules and would put them in the best position to obtain a first co-op requiring the use of Solidworks.

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Appendix A: ASME SolidWorks Pre-Survey Fall 2012

* Required Fields

Survey # * [ ] What is your GPA? * [ ] What year do you graduate? * [ ]

How familiar are you with the following features now? *

	Not Familiar	Little	Familiar	Quite	Very Familiar
Extrude	○	○	○	○	○
Extrude Cut	○	○	○	○	○
Revolve	○	○	○	○	○
Hole Wizard	○	○	○	○	○
Sweep	○	○	○	○	○
Loft	○	○	○	○	○
Linear Pattern	○	○	○	○	○
Chamfer	○	○	○	○	○
Fillet	○	○	○	○	○
Sheet Metal	○	○	○	○	○

How familiar is your knowledge with the following assembly skills now? *

	Not Familiar	Little	Familiar	Quite	Very Familiar
Mates	○	○	○	○	○
Build of Material	○	○	○	○	○
Motion Study	○	○	○	○	○

How familiar is your knowledge with the following drawing skills now? *

	Not Familiar	Little	Familiar	Quite	Very Familiar
Tolerances	○	○	○	○	○
Dimensioning	○	○	○	○	○

	Not Familiar	Little	Familiar	Quite	Very Familiar
Notes	☐	☐	☐	☐	☐
Material Callouts	☐	☐	☐	☐	☐

How familiar are you in the following practical engineering skills *

	Not Familiar	Little	Familiar	Quite	Very Familiar
Machining	☐	☐	☐	☐	☐
Manufacturing Techniques	☐	☐	☐	☐	☐

What interests you about Mechanical Engineering? (ex. Industries, subjects, disciplines,etc) *

What is your favorite engineering class you have taken thus far? *

Why are you taking this class? *

Describe your previous experiences with mechanical drawings and CAD *

Appendix B: ASME SolidWorks Post-Survey Fall 2012

* Required Fields

Survey Number * [ ] What is your GPA? * [ ] What year do you graduate? * [ ]

The instructors communicated ideas and information effectively *

- (•) Strongly Agree
- ( ) Agree
- ( ) Neutral
- ( ) Disagree
- ( ) Strongly Disagree

The instructors were effective in teaching this course *

- (•) Strongly Agree
- ( ) Agree
- ( ) Neutral
- ( ) Disagree
- ( ) Strongly Disagree

Having roving assistants helped me learn *

- ( ) Strongly Agree
- ( ) Agree
- ( ) Neutral
- ( ) Disagree
- ( ) Strongly Disagree

The lectures helped me to learn *

- ( ) Strongly Agree
- ( ) Agree
- ( ) Neutral
- ( ) Disagree
- ( ) Strongly Disagree

I am glad to have taken this course *

- ( ) Strongly Agree

- Agree
- Neutral
- Disagree
- Strongly Disagree

The class provided sufficient feedback to determine progress *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

This class improved my Solidworks Knowledge *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I learned a lot from this class *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I have developed additional Solidworks skills, and I now feel more prepared for co-op after taking this class *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

I did all of the assigned homework *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Did the homework help? *

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

How familiar are you with the following feature *

	Not Familiar	Little	Familiar	Quite	Very Familiar
Extrude					
Extrude Cut					
Revolve					
Revolve Cut					
Hole Wizard					
Sweep					
Loft					
Linear Pattern					
Chamfer					
Fillet					
Sheet Metal					

How familiar is your knowledge with the following assembly skills now? *

	Not Familiar	Little	Familiar	Quite	Very Familiar
Mates	☐	☐	☐	☐	☐
Build of Material	☐	☐	☐	☐	☐
Motion Study	☐	☐	☐	☐	☐

How familiar is your knowledge with the following drawing skills now? *

	Not Familiar	Little	Familiar	Quite	Very Familiar
Tolerances	☐	☐	☐	☐	☐
Dimensioning	☐	☐	☐	☐	☐
Notes	☐	☐	☐	☐	☐
Material Callouts	☐	☐	☐	☐	☐

How familiar are you in the following practical engineering skills? *

	Not Familiar	Little	Familiar	Quite	Very Familiar
Machining	☐	☐	☐	☐	☐
Manufacturing Techniques/Machines	☐	☐	☐	☐	☐

What could be done to improve this class? *

Do you feel you are a more desirable candidate to employers after taking this class and why? *

What were your favorite topics and why *

What were your least favorite topics and why *

Do you feel this class has given you the tools to expand on your Engineering interests *

If anything was too repetitive please list here *

Which teaching method did you prefer: having the tutorial on hand before the lecture or receiving it afterwards for reference? Why? *