



A Learning-centered Educational Paradigm: Case Study on Engineering Technology Students' Design, Problem-solving, Communication, and Group Skills

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Abstract

This case study explores how a learning-centered educational paradigm affects undergraduate engineering technology (ET) students' engineering design, problem-solving, communication, and group skills. Evidence for the study comes from twenty-three mechanical engineering technology students enrolled in a first-year engineering design and documentation (e.g., technical drawings) course. Part three of the four-part Classroom Activities and Outcomes Survey measured the extent to which the students believed they had made progress in a variety of learning and skill development areas because of the course (i.e., indirect assessment). The end-of-semester survey indicated that the learning-centered paradigm produced positive learning and skill gains in the four general content areas (i.e., factors) of engineering design, problem-solving, communication, and group skills. Additional student feedback from course evaluations provided evidence of positive reactions to the instructor, course, and active learning elements, such as the team project, group discussions, and self-assessments. The results support the general belief that a learning-centered educational paradigm will produce greater learning and skill gains than a teaching-centered paradigm in Science, Technology, Engineering, and Math (STEM) disciplines. The techniques used and the outcomes from the course have implications for not only future curriculum development but also ABET accreditation, which requires accredited ET programs to demonstrate that their graduates develop 11 competencies. This case study analyzes four of the 11 competencies and provides educators an active learning resource with classroom instructional materials for a first-year engineering design course.

Introduction

For over a decade, Michael Prince's article investigating the effectiveness of active learning in engineering education has been one of the most accessed and cited articles in the field (Prince, 2004). According to Google Scholar® on October 25, 2017, it has been cited over 3,500 times and was the most accessed Journal of Engineering Education article in 2016. Engineering and engineering technology (ET) faculty looking for alternatives to traditional teaching methods (i.e., lecturing) and researchers looking for a summary of relevant literature in the field often begin their search here. Prince (2004), provides evidence of *broad* but *uneven* support for elements and methods of active learning. In line with related literature, the article also emphasizes caution to the reader on drawing quick conclusions on the effectiveness of active learning as a *whole*.

Fast-forward ten years, Freeman et al. (2014) completes a metaanalysis of 225 studies comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses with at least some active learning versus traditional lecturing. The largest and most comprehensive study of its kind to date concluded that active learning boosts examination scores and lowers failure rates. Thus, "active learning increases student performance across the STEM disciplines" (Freeman et al., 2014, p. 8411). The article has quickly become another favorite for active learning research and curriculum development. According to Google Scholar on October 25, 2017, it had been cited over 1,400 times.

Prince (2004) and Freeman et al. (2014) are similar in that both studies present strong evidence for the general support of active learning. The difference is that Freeman et al. (2014) does not conclude with cautionary statements on the adoption of active learning in STEM, but instead clearly questions the logic in the continued use of traditional lecturing.

“Given our results, it is reasonable to raise concerns about the continued use of traditional lecturing as a control in future experiments. Instead, it may be more productive to focus on what we call second-generation research” (p. 8413), such as the intensity or type of the active learning used.

Research on active learning has finally reached a turning point. One may now reasonably argue that the answer to the broad question of if active learning works has sufficiently been answered. Prince (2004), Freeman et al. (2014), and similar research in agreement “allows us to be confident that, on average, engaging students through active learning strategies enhances learning” (Streveler & Menekse, 2017, p. 186). The engineering and ET community are now being called to be more precise when describing their active learning strategies and techniques; turning away from *does it work?* to *which types work?* and *for whom?*

This paper describes a single case in which a small sample of undergraduate mechanical engineering technology (MET) students took a learning-centered course on engineering design and documentation (e.g., technical drawings). Motivation for the course design was to help students develop stronger technical and professional skills/competencies through active learning (e.g., team project, group discussions, and self-assessments). The motivation for studying the case is to explore the relationship between a learning-centered educational paradigm and undergraduate MET students’ self-reported development of specific professional competencies. The motivation for publishing the case study is a direct response to the call by Streveler and Menekse (2017):

“We call on the engineering education community to take a more nuanced approach (i.e., done with extreme care and accuracy) to active learning. Instead of asking, does active learning work? One can now ask, what kind of active method produces the highest learning in specific settings, or with specific kinds of students?” (p. 189).

For this case study, the following were the research goals:

- Explore the effect of a learning-centered educational paradigm on MET students’ engineering design, problem-solving, communication (written and verbal), and group skill development.
- Access student perceptions of the course, instructor, and active learning elements via end-of-semester course evaluations (i.e., indirect assessment).
- Answer the call by Streveler and Menekse (2017).

Definitions

Although there are no universally accepted definitions for many of the terms used in this paper, the following list is representative of commonly accepted definitions as utilized in the published literature relating to higher education. The author has provided them to enhance clarity and consistency among readers.

- Paradigm. A frame of reference that determines how we perceive, interpret, and make sense out of how we educate students (Johnson, Johnson, & Smith, 2006, McManus, 2001).
- Teaching-centered paradigm. The traditional paradigm of higher education (i.e., widespread adoption) with discussions generally centering on the use of passive learning instructional methods (e.g., lecturing), and a classroom environment where the instructor *teaches* the subject to the student and expects them to learn it (i.e., instructor is central) (McManus, 2001).
- Learning-centered paradigm. Discussions generally center on the use of active learning instructional methods (e.g., project-based learning, group discussions, problem-based learning), and a classroom environment where the instructor *helps* the students learn the subject (i.e., instructor and student are partners) (McManus, 2001). Traditional instructional activities, such as homework, exams, quizzes, and lectures may also occur when the instructor is not acting as a coach or mentor.
- Passive Learning. The use of teacher-centered methods (i.e., teaching is the emphasis) favoring lectures presented by an instructor to an audience of students. (Menekse, Stump, Krause, & Chi, 2013).
- Active Learning. The use of learning-centered instructional methods (i.e., learning is the emphasis) that require students to do meaningful learning by participating in activities (Bonwell & Eison, 1991, Prince, 2004). The core is student engagement and dynamic involvement in the learning activity, often involving group work and higher-order thinking (Freeman et al., 2014).
- Project-Based Learning (PBL). A form of active learning in which learning activities are context specific, students participate in the learning process, and goals are achieved through social interaction and the sharing of knowledge (Kokotsaki, Menzies, & Wiggins, 2016). Distinction from active learning may be made by the extended length of time students work to investigate and respond to a complex question, problem, or challenge (Donnelly & Fitzmaurice, 2005) and that the work produces a realistic product or presentation (Jones, 1997).

Case Study

In the spring 2017 semester, twenty-four undergraduate students (20 male) enrolled in MET10200: Production Design and Specification at the Purdue Polytechnic New Albany campus, of which 58.33% were freshman ($n = 14$), 25.00% were sophomores ($n = 6$), 12.50% were juniors ($n = 3$), and 4.17% were seniors ($n = 1$). One student did not complete the course. All students majored in Mechanical Engineering Technology (MET), a major in the School of Engineering Technology (SoET), and were registered Purdue University students. The purpose of the course is to provide basic to intermediate competencies in technical drawing, computer-aided design (CAD), and design for manufacturing. The course learning outcome objectives (CLOOs) are as follows:

- Apply American National Standard drawing techniques unique to various specialty industrial manufacturing processes, in the production and interpretation of engineering drawings.

- Follow current American National Standards practices in generating a complete assembly/detail dimensioned set of drawings, given design intent and a mechanical design.
- Apply standard rules for numerical significance, maintenance of design intent, and with awareness of cost/benefit concerns when performing substitution or conversion of dimensional specifications to/from metric units.
- Use default specifications, standards documents and/or handbook data to verify design intent by calculating and documenting via standard practices, allowable limits for any dimension or feature on the drawing, given an engineering drawing with custom and standard parts.
- Use default specifications, standards documents and/or handbook data to verify design intent by calculating and documenting via standard practices, allowable limits and multi-part fits between parts for any dimension or part on the assembly, given engineering drawings for an assembly with custom and standard parts.
- Isolate, revise and document the changes to engineering drawing via standard practices, when given a drawing set and engineering change authorization.
- Seek answers to questions on technical specifications, company procedures, products or services, etc., using handbooks, national/international engineering standards, the internet or other references, to formally report, critique and/or present answers.
- Cooperate with all team members to complete the common goals of a team project.

The three credit hour course was scheduled to meet twice a week (two hours each time) in a typical CAD classroom/lab, containing desktop workstations (dual monitors), white board(s), projector(s), and printer(s). The author was the professor of record and independently designed the course based on Purdue University CLOOs. In course planning and preparation, the instructor adopted a learning-centered paradigm, while using a Learning Management System (LMS) (i.e., Blackboard) for course organization, file sharing, assignment posting/submission, grading, and testing. The instructor's goal was to create a learning environment in which students could learn to restructure the new information and their prior knowledge into new knowledge about the content, and practice using it. Course design included a combination of mini/bridging lectures (as needed), readings, group discussions, exams, assignments, and a team project. The course was approximately 5% lecturing and 95% active learning. The instructor used a weighted grading scale to assess students' overall performance (see Table 1).

Table 1. Overall Course Assessment

Category	Frequency (count)	Total Points Possible	Overall Grade Weight² (percent)
Participation/Attendance		10	5
Exams ¹	2	218	22.5
Assignments	11	143	22.5
Team Project	1	110	50

Notes. ¹Open book/notes, ²Proportional weighting applied

The instructor approximately divided class time over the 16-week course into the following activities and topics.

- Weeks 1-9, team project introduction and individual assignments with group discussions and self-assessments (as needed) on the following topics:
 - History of engineering graphics
 - Line conventions and lettering
 - Orthographic and pictorial views
 - Scales, fits, and fasteners
 - Dimensioning and tolerancing
 - General principles and conventions
 - Rectangular coordinate dimensioning (i.e., datum dimensioning or baseline dimensioning)
 - Geometric Dimensioning & Tolerancing (GD&T)
 - Engineering drawing practices
 - SOLIDWORK modeling (parts, assemblies, and drawings)
- Weeks 10-16, team project

Weeks 1-9

The instructor introduced the team project (i.e., scope, requirements, deliverables, due dates, etc.) on the first day of class and randomly formed each three person team ($n = 8$). However, during weeks 1-9 the instructor used normal class time to cover the topics listed above. See the following section for details on the team project.

During weeks 1-9, the instructor assigned 12 readings from the engineering graphics textbook (Planchard, 2015), handout(s), and/or the American Society of Mechanical Engineers (ASME) Y14.5-2009, Dimensioning and Tolerancing standard. Assigned readings were due at the beginning of the next class, which prompted a group discussion moderated by the instructor. Students' active involvement during group discussion and their ability to answer instructor directed questions concerning the reading material affected their overall participation grade (see Table 1). If deemed by the instructor that students failed to complete their readings, did not understand the material, and/or needed additional time on the topic he would give a mini/bridging lecture in class.

After roll call, group discussion, and lecture if needed, students generally used the rest of the class time to complete their homework assignment(s), which were focused on the readings and/or CAD development exercises using chapter problems or free instructional resources (Dassault Systèmes, n.d.). Figure 1 and Figure 2 are examples of multiview drawings that students had to create a three-dimensional (3D) model from, using SOLIDWORKS. In total, students completed twenty-four modeling exercises similar to Figure 1 and Figure 2. In addition, Figure 3 and Figure 4 are images of an assembly that students had to replicate based on textbook instruction, and Figure 5 and Figure 6 are images of the two different assemblies that students had to create a complete set of technical drawings for. Drawings had to be in accordance with (IAW) ASME Y14.5-2009 and use instructor supplied drawing templates. After submitting their drawings, the students performed self-assessments by comparing their work to that of the instructors. Their task was to identify and record the differences between the drawings in simple and concise (i.e., giving a lot of information clearly and in a few words) statements. Students used knowledge learned from the readings, classroom discussions, and instructor given resources (e.g., standards and specifications) to aid in locating drawing differences (i.e., errors).

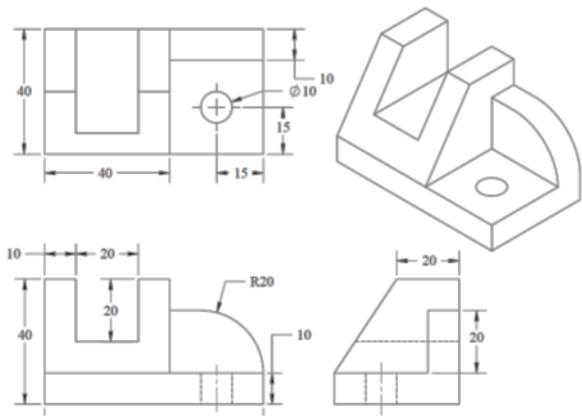


Figure 1. Part Modeling Example 1

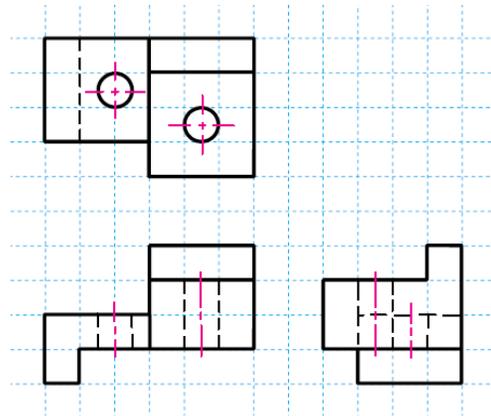


Figure 2. Part Modeling Example 2

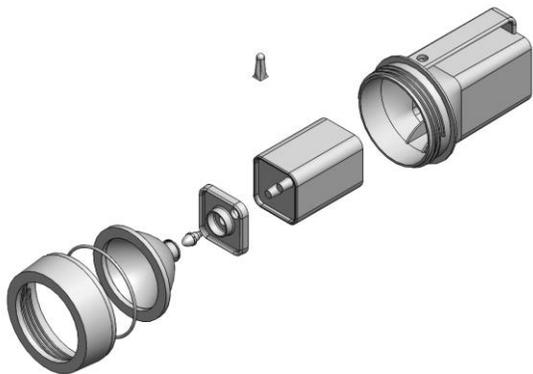


Figure 3. Flashlight Assembly - Exploded

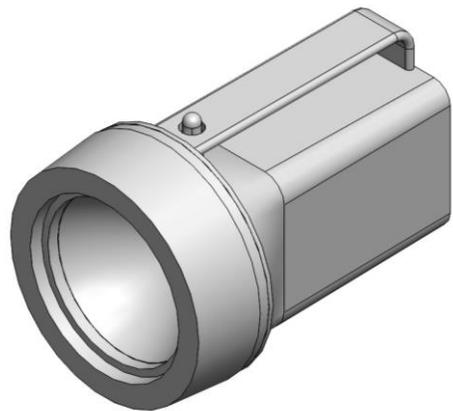


Figure 4. Flashlight Assembly - Collapsed

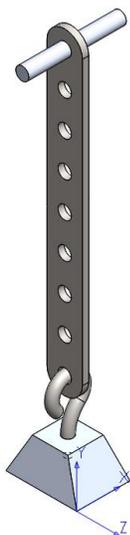


Figure 5. Weight-Link Assembly

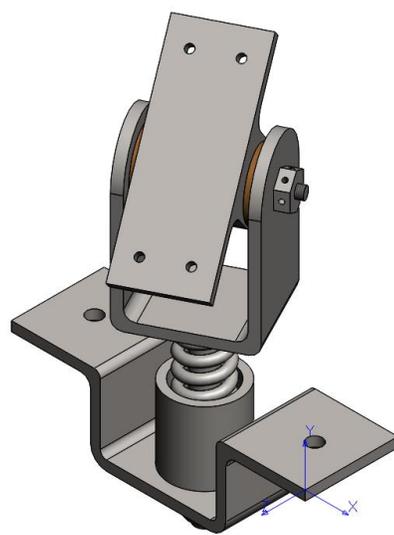


Figure 6. Shock Assembly

Weeks 10-16

During weeks 10-16, the instructor allowed teams to use class time to focus on completing the team project. Each team's overall objective was to design and build a catapult that used no commercial off-the-shelf (COTS) fasteners or adhesives and that could replace the human thrower when playing cornhole, which is a popular yard game (American Cornhole Association, n.d.). During the final day of class, teams competed against each other in a single elimination tournament. The objective of the project was to prepare students for industry-based design practices and learn by doing, a cornerstone of Purdue Polytechnic. The instructor categorized the project as an open-ended design challenge because each team was encouraged to be creative and innovative in how they would meet the project requirements. See Figure 7 for a general project sequence.

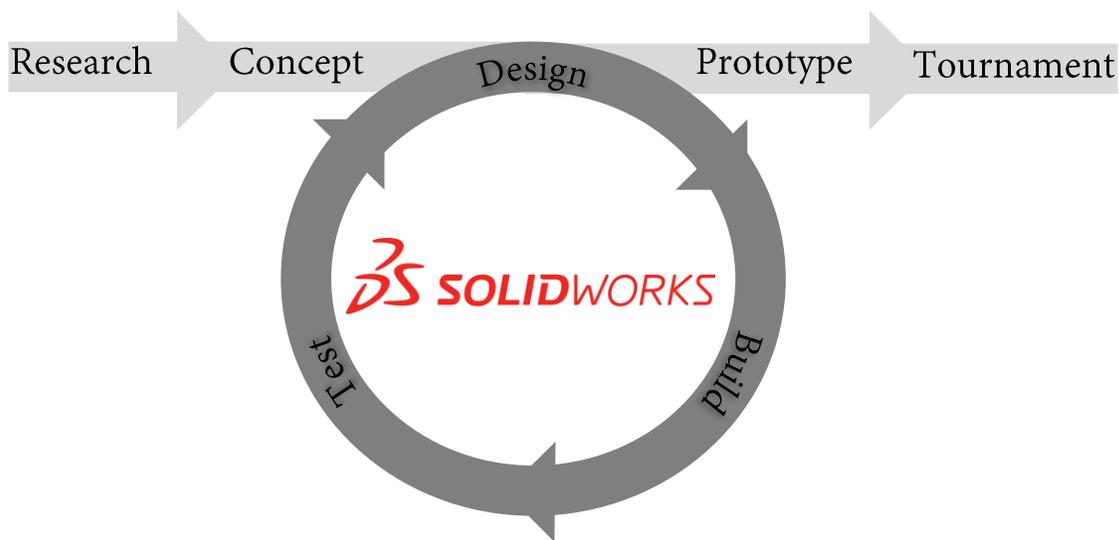


Figure 7. General Cornhole Catapult Project Sequence

The project deliverables included a research portfolio, CAD, a design review, and a functioning prototype. All deliverables were due the last day of class, except for the research proposal (\approx week 10) and design review (\approx week 14). The research portfolio was a document that contained at a minimum: catapult research, conceptual design(s), decision matrix, and team meeting minutes. The CAD deliverable consisted of SOLIDWORKS models (i.e., parts, assemblies, and drawings). Students submitted a zipped folder (i.e., Pack-n-Go) which contained all part, assembly (minimum one), and drawing files at completion. The instructor supplied the drawing, sheet, bill-of-material (BOM), revision table, and block templates. The drawings were created IAW with ASME Y14.5-2009 and consisted of each team's final catapult design (i.e., tournament prototype). Students used rectangular coordinate dimensioning and general tolerancing practices to define each part. It was highly encouraged that students begin drawings early and revise as needed based on manufacturing and testing. The design review was an informal meeting scheduled by the team with the instructor to review their progress and provide individualized guidance as needed.

Manufacturing of the catapults primarily occurred in the Purdue BoilerMAKER Lab. The lab contains common hand tools and subtractive manufacturing equipment, such as saws and drills. It also contains large professional level computer numerical control (CNC) machines: lathe, 4-axis mill, and router/plasma cutter. The lab has been equipped with six fused deposition modeling (FDM) 3D printers, and two laser cutting, etching, and engraving machines. Catapult construction was *limited* to the following materials:

- Instructor supplied (each team received):
 - 1 sheet of 4' wide x 8' long x 3/8" thick plywood sheathing
 - 8' of multi-purpose 3/8" nylon braided rope
 - 8' of multi-purpose 3/16" nylon bungee cord
 - 1' of 1/2" diameter weldable steel round rod (cold rolled)
 - 1 sheet of 6" wide x 6" long x $\approx .015$ " thick leather sheet
 - 1 tile of 6" wide x 6" tall x 1/4" thick HDPE plastic
 - 1 solid carbide 2 flute straight end mill
- Lab supplied:
 - 3D printer filament
 - No hardware (i.e., screws, bolts, nuts, washers, etc.) may be printed
 - Scraps (testing purposes only)
 - Welding materials (counter weight only)
- Student supplied materials:
 - Counter weight (if needed)

At the completion of the project, students had the opportunity to submit a peer review of each team member (see Appendix – Peer Evaluation Form). The instructor used the peer review data and self-observations to adjust individual students' project grade as needed. The professor used a self-created rubric to aid in evaluating each teams' performance (see Appendix – Project Rubric).

Outcomes

Course Surveys

Students at the end of each semester anonymously took a Purdue University created and circulated course evaluation survey. The survey contains demographic-based questions, Purdue University wide questions about course and instructor, course specific questions, and optional written comments section. Based on the purpose of this paper, the author has chosen to present the survey results for the university questions. On the two university questions, students self-reported on their satisfaction of the course and instructor by selecting a response on a five-point Likert scale (where: 5 = extremely good, 4 = good, 3 = fair, 2 = poor, and 1 = very poor) that best reflected their perception (see Table 2).

Table 2. End of Semester Evaluations

Questions	<i>M (SD)</i> <i>n = 19/23</i>
University Questions:	
a. Overall, I would rate this course as	4.60 (.60)
b. Overall, I would rate this instructor as	4.80 (.57)

Notes. *n* = number of respondents/possible number of respondents, 1 = very poor, 2 = poor, 3 = fair, 4 = good, and 5 = extremely good

Classroom Activities and Outcomes Survey

At the end of the course, each student completed an online (i.e., Qualtrics) survey. The survey was part three of the four-part Classroom Activities and Outcomes Survey, which was developed by the Center for the Study of Higher Education at Pennsylvania State University as part of the evaluation of Engineering Coalition of Schools for Excellence in Education and Leadership. The indirect assessment measured the extent to which the students believed they had made progress in a variety of engineering related skills as a result of taking the course by selecting a response on a four-point Likert scale (where 1 = none at all, 2 = a slight amount, 3 = a moderate amount, and 4 = a great deal) that best reflected their perception (see Table 3). It is described in detail by Terenzini, Cabrera, Colbeck, Bjorklund, and Parente (2001) and Terenzini, Cabrera, Colbeck, Parente, and Bjorklund (2001), therefore this paper provides only a brief description.

The survey items were originally developed to reflect as closely as possible ABET's 11 learning outcomes for undergraduate engineering students. Terenzini, Cabrera, Colbeck, Parente, et al. (2001), performed a factor analysis on the original 27 survey items which produced four factors, which they labeled to reflect the general content areas of design skills, problem-solving skills, communication skills, and group skills. This study has used a modified version of part three (<http://www.pearweb.org/atis/tools/51>) and those same factors in reporting students' self-reported learning and skill gains.

Table 3. Course Related Skill Gains

Factor	<i>M (SD)</i> <i>n = 17/23</i>
Design Skills	
a. Understanding of what engineers “do” in industry or as faculty members	3.41 (0.69)
b. Understanding of engineering as a field that often involves non-technical considerations (e.g., economic, political, ethical, and/or social issues)	3.06 (0.87)
c. Knowledge and understanding of the language of design in engineering	3.53 (0.61)
d. Knowledge and understanding of the process of design in engineering	3.71 (0.57)
e. Your ability to “do” design	2.94 (1.06)
Problem-Solving Skills	
f. Your ability to solve an unstructured problem (that is, one for which no single “right” answer exists)	3.24 (0.73)
g. Your ability to identify the knowledge, resources, and people needed to solve an unstructured problem	3.35 (0.76)
h. Your ability to evaluate arguments and evidence so that the strengths and weaknesses of competing alternatives can be judged	3.41 (0.69)
i. Your ability to apply an abstract concept or idea to a real problem or situation	3.24 (0.81)
j. Your ability to divide unstructured problems into manageable components	3.35 (0.68)
Communication Skills	
k. Your ability to clearly describe a problem orally	3.18 (0.86)
l. Your ability to clearly describe a problem in writing	3.06 (0.87)
Group Skills	
m. Your ability to develop ways to resolve conflict and reach agreement in a group	3.12 (1.02)
n. Your ability to pay attention to the feelings of all group members	3.00 (0.84)
o. Your ability to listen to the ideas of others with an open mind	3.35 (0.76)
p. Your ability to work on collaborative projects as a member of a team	3.41 (0.69)
q. Your ability to organize information into categories, distinctions, or frameworks that will aid comprehension	3.35 (0.76)
r. Your ability to ask probing questions that clarify facts, concepts, or relationships	3.24 (0.81)
s. After evaluating the alternatives generated, to develop a new alternative that combines the best qualities and avoids the disadvantages of the previous alternatives	3.35 (0.76)
Other, Unscaled Items	
t. Your ability to develop several methods that might be used to solve an unstructured problem	3.06 (0.87)
u. Your ability to identify the tasks needed to solve an unstructured problem	3.35 (0.76)
v. Your ability to visualize what the product of a project would look like	3.47 (0.70)
w. Your ability to weigh the pros and cons of possible solutions to a problem	3.53 (0.61)
x. Your ability to figure out what changes are needed in prototypes so that the final engineering project meets design specifications	3.41 (0.77)

Notes. *n* = number of respondents/possible number of respondents, bolded items (see Discussion Section), 1 = none at all, 2 = a slight amount, 3 = a moderate amount, and 4 = a great deal

Project Examples

To inspire future adoption of the project by others, the author has shared a sample of students' finished projects (note that no COTS fasteners or adhesives are used).



Figure 8. Catapult Example 1 – Side View



Figure 9. Catapult Example 1 – Back View



Figure 10. Catapult Example 2 – Back View



Figure 11. Catapult Example 2 – Side View

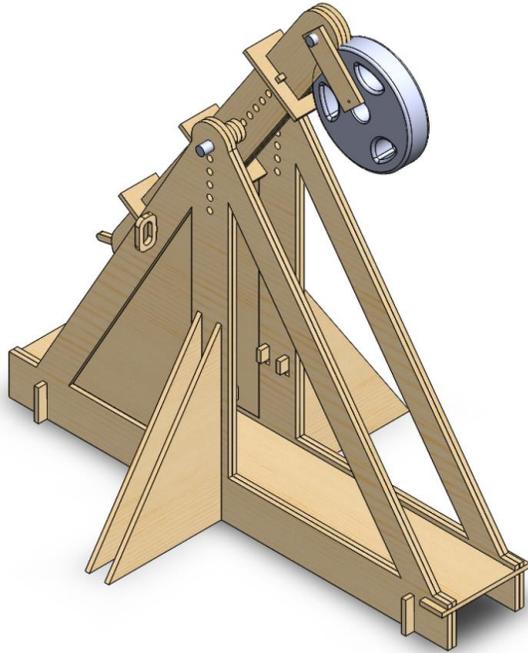


Figure 12. Catapult Example 1 – CAD Assembly

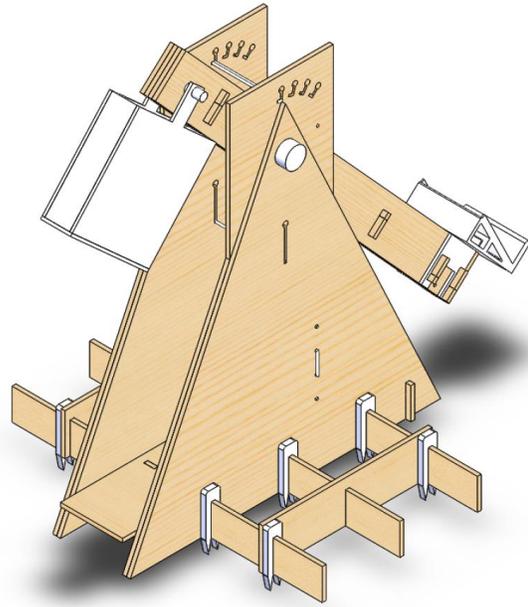


Figure 13. Catapult Example 2 – CAD Assembly

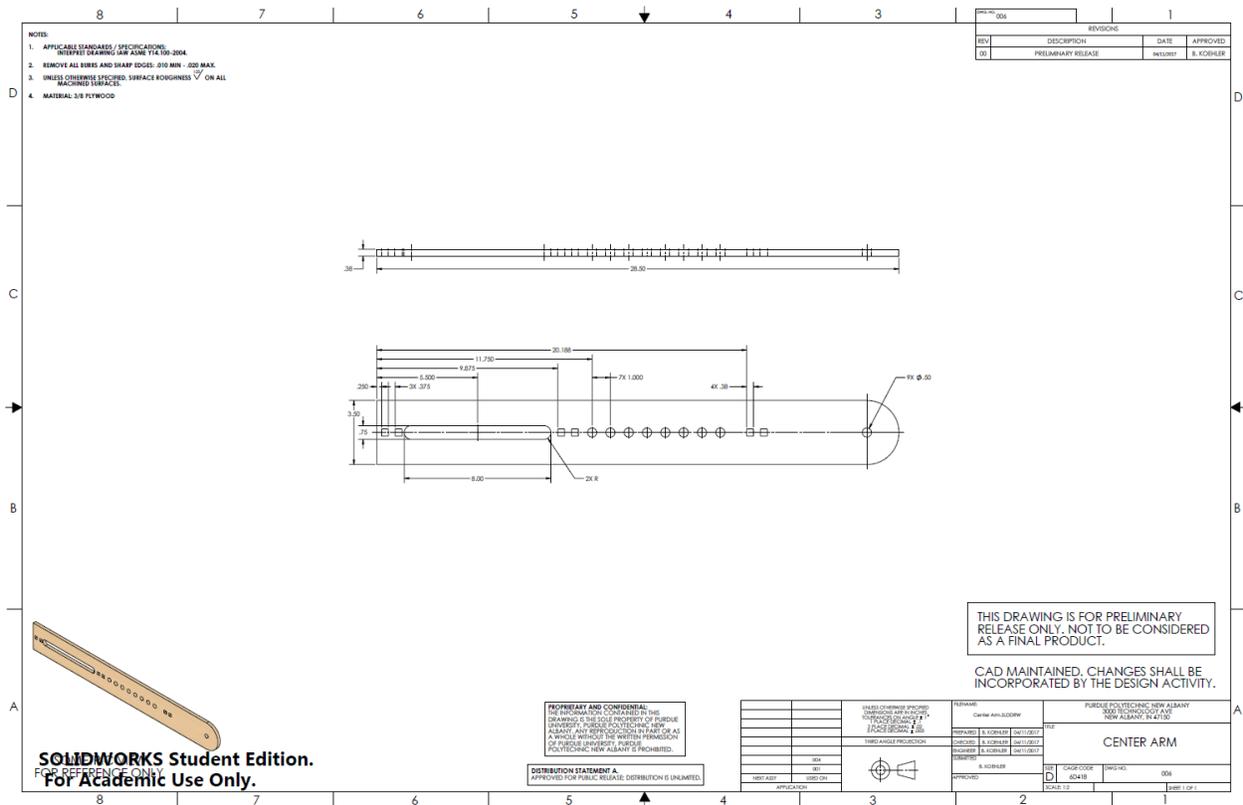


Figure 14. Dimensioned Multiview Drawing

Discussion

Based on the data reported in Table 3, students believe that over the course of a semester they have moderately to significantly improved their skills in the general content areas of engineering design ($M = 3.33$), problem-solving ($M = 3.32$), communication ($M = 3.12$), and group skills ($M = 3.26$). There are however, several individual survey items under each skill factor that welcome discussion.

Item *e* (your ability to “do” design) under the engineering design skill factor, received the lowest average score ($M = 2.94$) across all survey items and is a noticeably lower than the other factor items. This may be a result of the ambiguous nature of the verb used in the question, which could have resulted in respondent error ($SD = 1.06$). Respondents may also perceive that the question implies a need for higher order thinking skills due to the vertical movement on Bloom’s Taxonomy from knowledge and comprehension to application (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956).

Item *d* (knowledge and understanding of the process of design in engineering) under the engineering design skill factor, received the highest average score ($M = 3.71$) across all survey items, which is unexpected. MET10200 is a freshman second-semester course, and while the students have completed a few design projects in other courses, none required a thorough understanding and/or participation in all the common steps (e.g., problem identification, refinement, analysis, documentation, etc.) of the engineering design process. Design projects at this complexity and level occur during a two-semester senior capstone and/or internship. In addition, neither the university, department, nor the campus have a documented design process that all faculty/staff agree to use. This results in the students viewing and using various examples in multiple courses, often causing confusion and resulting in an incomplete (i.e., simplified) understanding of the engineering design process. The idea of creating a design process specifically for the campus, based on published works has been proposed and received positive feedback.

Item *k* (your ability to clearly describe a problem orally) and *l* (your ability to clearly describe a problem in writing) under the engineering communication skill factor, both received lower than expected average scores. The lower than expected score for item *k* ($M = 3.18$) could be a result of the team project not requiring a final oral presentation, however; teams members were in consistent oral communication with themselves and the instructor. The lower than expected score on item *l* ($M = 3.06$) may be a result of students not viewing drawings as a form of written communication. The creation of dimensioned and toleranced technical drawings IAW national standards and specifications was core to the course as a whole. The students’ ability to do so also affects multiple CLOOs. Technical drawings are the language of engineers and their existence is purely to communicate information to stakeholders (e.g., manufacturing, quality control, management, etc.). A major deliverable of the project was a drawing package of the final prototype. Based on the complexity of the catapult design, some teams had to create 30 or more drawings, which was a significant challenge due to time constraints and CAD skill level.

Item *n* (your ability to pay attention to the feelings of all group members) under the engineering group skills factor, received the second lowest average score ($M = 3.00$) across all survey items, which was expected. The course does not have lessons on interpersonal skills, such as active listening and empathy, nor have they covered the topics in other courses. However, empathy is the centerpiece of the human-centered design process, more commonly referred to Design

Thinking, which the Stanford d.school popularized. A future research study could be to implement Design Thinking curricula into the course and see how it affects the outcomes.

Item t 's (your ability to develop several methods that might be used to solve an unstructured problem) average score ($M = 3.06$) under the unscaled items was expected. The instructor introduced the project on the first day of class, thus each team had approximately 16 weeks to complete the project. However, even after the instructor stated that the project would require a significant amount of time outside of class, the majority of the teams did not begin design efforts until approximately week 10. This significantly limited each teams' ability to create multiple designs and prototypes. As seen in Figure 7, the instructor anticipated that at a minimum teams would have iterative CAD design, but this was not observed.

On average, the course ($M = 4.60$) and instructor ($M = 4.80$) were viewed by the students as good to extremely good. It is unknown how each instructional activity (i.e., readings, homework assignments, group discussions, self-assessments, and team project) over the 16-weeks specifically affected each students' learning and skill gains. However, the instructor believes the team project made the largest impact on the ET students' engineering design, problem-solving, communication, and group skills. Students' comments about the project were generally positive other than a few requesting that it be introduced earlier in the semester and that manufacturing lab space and equipment availability was limited. The project cannot be introduced any earlier than the first day of class; however, the instructor needs to emphasize the importance of starting early and move up the research portfolio and design review due dates. Lab space and equipment access will continue to be a bottleneck as other courses have ongoing projects, however; the instructor also observed that the majority of the teams failed to utilize the full capacity of the manufacturing lab. Teams consistently waited in line to use the larger laser cutter, which can hold a full sheet of plywood, instead of cutting the plywood to size so that they may use the smaller laser. Teams also failed often to use basic shop tools, such as a table saw, band saw, and jig saw to aid in the manufacturing process. Additional changes to the project and justifications for them are as follows:

- Thinner plywood sheathing: 3/8" thickness to 1/4" thickness
 - Decrease cutting times and increase throughput
- Shorter distance between cornhole boards: 20' to 13'6"
 - Increase probability of scoring and decrease counterweight needed
- Lighter cornhole bags: $\approx 6'' \times 6''$ to $4'' \times 4''$ and 16 oz. to 3.65 oz.
 - Increase probability of scoring and decrease counterweight needed
- Revise project rubric: include *novelty* in creativity/innovation criteria and add *professionalism* criteria line
 - Aid in assessment and encourage student professionalism in classroom and lab

Limitations

“The results of this study are limited in many ways. Generalization of findings to other colleges and universities should be approached with caution, as ... students participating in the study were not random” (Cabrera, Colbeck, & Terenzini, 2001, p. 341). Strauss and Terenzini (2005), should be referenced concerning limitations and concerns focused on the Classroom Activities and Outcomes Survey and ABET's a-k criteria. The study consisted of a relatively small sample

size, which was predominately male and white so generalizability of the findings should be limited (Pawley, 2017); however, continued data collection will take place in the spring of 2018.

Finally, more direct assessments, such as standardized tests or demonstrations of skills are often favored over indirect assessments (i.e., self-reporting) and could yield different results. However, research suggests that self-reported measures of learning can be valuable (Cabrera et al., 2001) and a “meaningful assessment program would use both direct and indirect assessments from a variety of sources (i.e., students, alumni, faculty, employers, etc.)” (Roger, 2006, p. 1).

Conclusion

In conclusion, no single research study can completely answer the recent call by Streveler and Menekse (2017). Just as it has taken decades for most of the current engineering and ET education community to support the notion that active learning works. It will now take years of new research with a more nuanced approach before we know which types of active learning and for which students it works best. This case study is only part of the solution, but it shows that a learning-centered paradigm in a first-year engineering design and documentation (i.e., technical drawings) course will improve MET students’ engineering design, problem-solving, communication, and group skills. These are four professional competencies that are not only crucial for the 21st century engineer but also for ABET accreditation.

References

- American Cornhole Association (n.d.). *How To Play Cornhole / Corn Hole / Bean Bag Toss: Official Cornhole Rules*. Retrieved from: <https://www.playcornhole.org/aca-official-rules-of-cornhole-corn-toss/>
- Bloom, B. S., Englehart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R., (Eds.). (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain*. New York, NY: Longmans.
- Bonwell, C., & Eison, J. (1991). *Active learning: Creating excitement in the classroom. AEHE-ERIC higher education report No. 1*. Washington, DC: George Washington University.
- Cabrera, A. F., Colbeck, C. L., & Terenzini, P. T. (2001). Developing performance indicators for assessing classroom teaching practices and student learning: The case of engineering. *Research in Higher Education* 42(3), 327-352. Retrieved from www.jstor.org
- Dassault Systèmes (n.d.). *Engineering Drawing Tutorials for Visualization*. Retrieved from: <https://www.solidworks.com/sw/education/engineering-drawing-tutorial-visualization.htm>
- Donnelly, R., & Fitzmaurice, M. (2005). Collaborative project-based learning and problem-based learning in higher education: a consideration of tutor and student roles in learner-focused strategies. In G. O'Neill, S. Moore & B. McMullin (Eds.), *Emerging issues in the practice of university learning and teaching*. Dublin, Ireland: All Ireland Society for Higher Education (AISHE).
- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences* 111(23), 8410-8415. doi: 10.1073/pnas.1319030111
- Johnson, D. W., Johnson, R. T., & Smith, K. A. (2006). *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book Company.

- Jones, B. F. (1997). *Real-life problem solving: A collaborative approach to interdisciplinary learning*. M. C. Moffitt & R. M. Claudette (Eds.). Washington, DC: American Psychological Association.
- Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools* 19(3), 267-277. doi: 10.1177/1365480216659733
- McManus, D. A. (2001). The two paradigms of education and the peer review of teaching. *Journal of Geoscience Education* 49(5), 423-434. doi: 10.5408/1089-9995-49.5.423
- Menekse, M., Stump, G. S., Krause, S., & Chi, M. T. H. (2013). Differentiated overt learning activities for effective instruction in engineering classrooms. *Journal of Engineering Education* 102(3), 346-374. doi: 10.1002/jee.20021
- Pawley, A. L. (2017). Shifting the “default”: The case for making diversity the expected condition for engineering education and making whiteness and maleness visible. *Journal of Engineering Education* 106(4), 531-533. doi: 10.1002/jee.20181
- Planchard, D. (2015). *Engineering Graphics with SOLIDWORKS 2015 and Video Instruction: A Step-by-Step Project Based Approach*. Mission, KS: SDC Publications.
- Prince, M. J. (2004). Does active learning work? A review of the research. *Journal of Engineering Education* 93(3), 223-231. doi: 10.1002/j.2168-9830.2004.tb00809.x
- Roger, G. (2006). *Assessment 101: Assessment tips with Gloria Rogers, Ph.D.: Direct and indirect assessment*. Retrieved from: www.abet.org/wp-content/uploads/2015/04/direct-and-indirect-assessment.pdf
- Strauss, L. C., & Terenzini, P. T. (2005). *Assessing student performance on EC2000 criterion 3.a-k*. Portland, OR. Washington, DC: American Society for Engineering Education.
- Streveler, R. A., & Menekse, M. (2017). Taking a closer look at active learning. *Journal of Engineering Education* 106(2), 186-190. doi: 10.1002/jee.20160
- Terenzini, P. T., Cabrera, A. F., Colbeck, C. L., Bjorklund, S. A., & Parente, J. M. (2001). Racial and ethnic diversity in the classroom: Does it promote student learning? *Journal of Higher Education* 72(5), 509-531. Retrieved from www.jstor.org
- Terenzini, P. T., Cabrera, A. F., Colbeck, C. L., Parente, J. M., & Bjorklund, S. A. (2001). Collaborative learning vs. Lecture/discussion: Students’ reported learning gains. *Journal of Engineering Education* 90(1), 123-130. doi: 10.1002/j.2168-9830.2001.tb00579.x

Appendix

Peer Evaluation Form

Name _____ Class Period _____ Date _____

Write the names of your group members in the numbered boxes. Then, assign yourself a value for each listed attribute. Finally, do the same for each of your group members and total all of the values.

Values: 5=Superior 4=Above Average 3=Average 2=Below Average 1=Weak

Attribute	Myself	1.INSERT NAME	2.INSERT NAME	3.INSERT NAME	4.INSERT NAME
Participated in group discussions.					
Helped keep the group on task.					
Contributed useful ideas.					
How much work was done.					
Quality of completed work					
Totals					

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Group Self Evaluation Checklist

Name _____ Class Period _____ Date _____

Topic of Study _____ Group Members' Names _____

As a team, decide which answer best suits the way your team worked together. Then, complete the remaining sentences.

We finished our task on time, and we did a good job! YES NO

We encouraged each other and we cooperated with each other. YES NO

We used quiet voices in our communications. YES NO

We each shared our ideas, then listened and valued each other's ideas. YES NO

We did best at

Next time we could improve at

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Project Rubric

Criteria	Levels of Achievement			
	Proficient	Emerging	Developing	Deficient
Computer-Aided Design (CAD)	Demonstrates high level of competency with computer-aided design tools. Part and assembly files are complete and contain no problems/errors. Drawings are complete and are always in-accordance-with ASME Y14.5-2009. Exceeds or meets project requirements for CAD.	Demonstrates moderate level of competency with computer-aided design tools. Part and assembly files are complete and contain minor problems/errors. Drawings are complete and are sometimes in-accordance-with ASME Y14.5-2009. Meets project requirements for CAD.	Demonstrates low level of competency with computer-aided design tools. Part and assembly files are incomplete and contain moderate problems/errors. Drawings are incomplete and are almost never in-accordance-with ASME Y14.5-2009. Does not meet project requirements for CAD.	Demonstrates no level of competency with computer-aided design tools. Part and assembly files are incomplete and contain serious problems/errors. Drawings are incomplete and are never in-accordance-with ASME Y14.5-2009. Does not meet project requirements for CAD.
Physical Prototype	Demonstrates high level of competency with additive and subtractive manufacturing. Physical prototype is complete and functional. Exceeds or meets project requirements for physical prototype.	Demonstrates moderate level of competency with additive and subtractive manufacturing. Physical prototype is complete and functional. Meets project requirements for physical prototype.	Demonstrates low level of competency with additive and subtractive manufacturing. Physical prototype is incomplete and nonfunctional. Does not meet project requirements for physical prototype.	Demonstrates no level of competency with additive and subtractive manufacturing. Physical prototype is incomplete and nonfunctional. Does not meet project requirements for physical prototype.
Creativity/Innovation	Demonstrates high level of creativity/innovation	Demonstrates moderate level of creativity/innovation	Demonstrates low level of creativity/innovation	Demonstrates no level of creativity/innovation