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Exploring Engineering Technology Students' Competencies in an Introductory Computer-Aided Drafting and Design Course: A Follow-on Study

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Computer-Aided Drafting and Design (CAD&D), Competency, Active Learning, Project-Based Learning (PBL)

PEER-reviewed Research Paper

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Exploring Engineering Technology Students' Competencies in an Introductory Computer-Aided Drafting and Design Course: A Follow-on Study

ABSTRACT

This descriptive research paper explores the degree to which an introductory computer-aided drafting and design (CAD&D) course impacted engineering technology (ET) students' self-reported competencies (i.e., a cluster of related knowledge, skills, and abilities). The student-centered course, which consisted of approximately 95% active learning, included a 16-week semi-open design challenge with a moderately-structured problem. Four competency areas, which are included in a recent US Department of Labor's Engineering Competency Model (ECM), were analyzed. A classroom activities and outcomes survey measured the degree to which 42 students from four cohorts over two consecutive years believed they had made progress in design, problem-solving, communication, and group/teamwork as a result of taking the course. The end-of-semester survey indicated positive self-reported progress in all four competency areas. Furthermore, additional student feedback from course evaluations provided evidence of positive reactions to the instructor, course, and active learning activities. This paper provides additional details and data from the two years following the 2017 pilot study. It also cross-analyzes the team project against the Gold Standard Project-Based Learning (PBL) Model's eight essential project design elements.

INTRODUCTION

Administrators, faculty, and students can rest assured that modern learning environments and innovative classroom practices are developing many of the competencies (i.e., a cluster of related knowledge, skills, and abilities) required of engineering technology (ET) students in today's global workforce. However, the ET research community must continue to discover how current practices are preparing graduates since curriculums, programs, and schools continue to evolve (Lincoln, 2015). The process of discovering which learning environments produce particular professional and technical competencies for particular students is not complete. In order to do so, researchers need to ask diverse research questions and/or state focused research objectives while accurately describing with precise detail (i.e., greater than that available in existing literature) the instructional method used and the population involved (Streveler & Menekse, 2017).

A recently revised U.S. Department of Labor-sponsored framework, titled the Engineering Competency Model (ECM), lists over 30 unique and essential competency areas across a multi-tiered pyramid that are required in the current engineering workforce. (Leslie, 2016; The Employment and Training Administration & American Association of Engineering Societies, n.d.). Many are also applicable to the ET and/or applied engineering workforce, as there is often overlap. The model serves "to assist in understanding the core set of abilities needed to enter the engineering profession" (Leslie, 2016, p. 3). As seen in Figure 1, each tier covers a different set of competencies.

- Tiers 1 (personal effectiveness), 2 (academic), and 3 (workplace) represent the soft/professional and work readiness skills;
- Tiers 4 and 5 show the industry-related competencies needed to create career lattices within an industry;
- Upper tiers represent occupation-related competencies (e.g., to define performance in a workplace, to design competency-based curriculum, to articulate the requirements for an occupational credential).

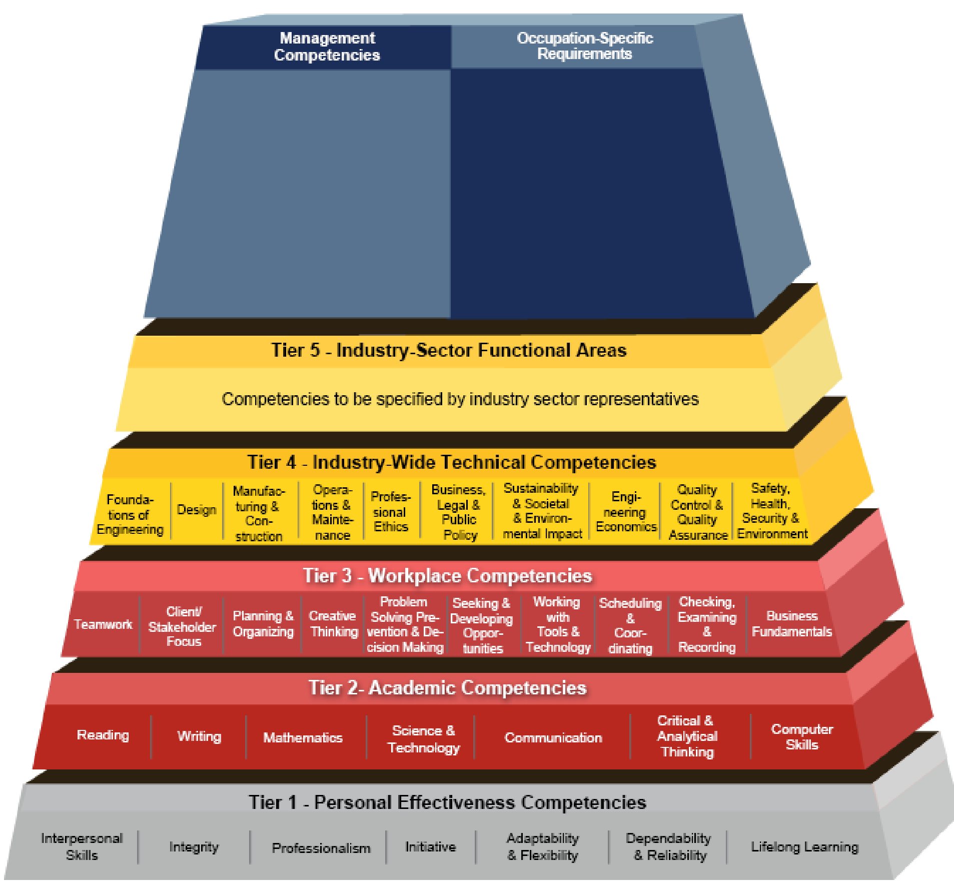
The pure magnitude (i.e., complexity and quantity) of information in the ECM or similar competency maps, such as the working model being created as part of the multi-phase initiative by the American

Society for Engineering Education (ASEE) to Transform Undergraduate Education in Engineering (TUEE) (ASEE, 2018), may shock many administrators, educators, and/or students. Yet, it should not. Graduates' readiness, including students coming from Science, Technology, Engineering, and Mathematics (STEM) fields has been under investigation for years (ASEE Corporate Member Council, 2020; Hart Research Associates, 2013; Hundley, 2015). The National Association of Colleges and Employers (2016) defines readiness as "the attainment and demonstration of requisite competencies that broadly prepare college graduates for a successful transition into the workplace." Competencies may go by other names, such as 21st-century skills, cross-curricular skills, soft skills, professional skills, interdisciplinary skills, habits of mind and work, deeper learning, readiness skills, attributes, or success skills. Regardless, there is agreement that students need more than basic subject-area knowledge to succeed across college, career, and life (Larmer, Mergendoller, & Boss, 2015). The 21st-century ET and applied engineering graduate needs to be a T-shaped professional (see Figure 2): one who has deep disciplinary knowledge and a range of competencies that can cross many disciplines (Gardner & Estry, 2017).

No single type of learning experience (e.g., lecture, lab, assignment, exam, project, course), instructional method (e.g., flipped class, game-based, direct), or element of the learning environment (e.g., people within, technology used, classroom layout, social and cultural environment) will deliver all the knowledge, skills, and abilities (KSAs) required of graduates. It takes various lengths of time and multiple learning opportunities, using a mixture of instructional methods, for students to learn the various competencies. In other words, a one-size-fits-all approach will not work. There is, however, strong evidence demonstrating that when students actively participate in constructing their own knowledge (i.e. constructivism), they gain a deeper understanding, more generalizable knowledge, and greater motivation and engagement to learn (Larmer et al., 2015).

Figure 1: Engineering Competency Model (Used with Permission)

Key



Project-based learning (PBL) is an active learning-based instructional method shown to foster effective learning and develop the many professional and technical skills required of students (Bjorklund, Parente, & Sathianathan, 2004; Durkin, 2016; Spezia, 2009). Krajcik and Shin (2014) write, "Project-based learning allows students to learn by doing, to apply ideas, and to solve problems. In so doing, students, engage in real-world activities similar to those of professional scientists" (p. 275). PBL is only one of the many student- or learning-centered methods used in engineering, ET, and applied engineering instruction. Others include inquiry learning, problem-based learning, case-based teaching, discovery learning, and just-in-time (JIT) learning (Prince & Felder, 2006). PBL's inductive nature (i.e., the student is more responsible for their learning experience) and the ability to include collaboration (team-based PBL), often considered essential, have made it one of the most popular methods. However, with popularity and a fast rate of adoption, problems can often occur with PBL. Larmer (2015) concludes that two problems may occur if PBL is not done well: "first, we will see a lot of assignments and activities that are labeled as projects, but which are not rigorous PBL, and student learning will suffer. Or, we will see projects backfire on underprepared teachers and result in wasted time, frustration, and failure to understand the possibilities of PBL" (p. 1).

Figure 2: T-Professional (Used with Permission)

It is important that PBL be distinguishable from cookbook-like lab experiments and simple (i.e., unchallenging), short (i.e., completion in a day(s), not weeks), and inauthentic (i.e., not representative of practices of professionals who work in the discipline) course work that does not produce a realistic product and/or allow for any reflection (Donnelly & Fitzmaurice, 2005; Jones, 1997). Using a comprehensive practice- and research-based model for PBL, such as the Gold Standard PBL Model published in 2015 by the Buck Institute of Education (see Figure 3), can help educators at all levels and in any discipline (Larmer et al., 2015). Horton, Jordan, Weiner, and Lande (2018) used the model in a recent study to analyze hackathon environments for the presence of key project-based learning characteristics. Taleyarkhan, Dasgupta, Garcia, and Magana (2018) used the model, similar to the author, to aid in describing a project in terms of how the eight essential project design elements were or were not met.

PBL is also a common instructional method used to teach students design, a term often interchangeable with design thinking (Taleyarkhan et al., 2018). Design spines and or design threads in post-secondary education are generally considered a multi-year sequence of hands-on design, build, test, and document courses where individuals and/or teams are presented with increasingly difficult projects (Danielson & Kirkpatrick, 2012). The spine typically consists of four or more courses, spread across multiple grade levels, and have been established for a variety of academic programs/majors: chemical (Datye et al., 2020), mechanical (Lulay, Dillon, Doughty, Munro, & Vijlee, 2015), manufacturing technology (Chattopadhyay, 2006), multidisciplinary (Arizona Board of Regents & University of Arizona, 2021; The University of Indianapolis, 2021), etc. They often begin in freshman year with a cornerstone course and end with a senior capstone course, which "concentrates on device/system design followed by analysis, building, testing, and operation with industry-supported projects" (Kirkpatrick & Danielson, 2012, p. 39). A CAD&D course(s) is often one of the courses a student takes early within the spine (Gallois & Sheppard, 1999).

Figure 3: Gold Standard PBL Model (Used with Permission)

PURPOSE

Streveler and Menekse (2017) recently called for the engineering education community, including engineering, ET, and applied engineering, to take a more nuanced view of active learning. The author was motivated to contribute to the call by providing this work, which focuses research objectives concerning active learning and provides accurate and precise details of the learning experience under investigation. The objectives are to explore, through indirect assessments (Roger, 2006), how an introductory computer-aided drafting and design (CAD&D) course impacted ET students' (1) design, problem-solving, communication, and group/teamwork competencies, and (2) perceptions of the instructor and course, specifically the active learning instructional activities.

The author piloted the research in 2017 with a single case study (i.e., the first cohort), which showed that the learning-centered paradigm produced positive learning and skill gains in the four competency areas for ET students (Webster, 2018). This paper provides additional details, including background, data, analysis, discussion, and conclusions from the two years following the 2017 case study. The justifications for this follow-on paper are largely due to the inability of the 2017 case study to (1) identify and/or confirm data trends with only one data set, (2) validate the results and describe in detail the learning experience.

METHODOLOGY

The convenience sample data (N = 42) for this paper comes from four cohorts of Purdue University students located at Purdue Polytechnic New Albany, over the 2018 and 2019 spring semesters (two sections each semester), of which seventeen (40.48%) were freshmen, sixteen (38.10%) were sophomores, six (14.29%) were juniors, and three (7.14%) were seniors. Grade classification was determined by credit hours completed. Thirty-four (80.95%) students majored in Mechanical Engineering Technology (MET), six (14.29%) in Mechatronics Engineering Technology (MHET), and two (4.76%) in Engineering Technology. All majors are part of the School of Engineering Technology (SoET). Four (9.52%) students identified as female and 38 (90.48%) as male. Thirty-one (73.81%) were between

18–25, nine (21.43%) between 26–34, and two (4.76%) between 35–54 years of age, respectively. The first cohort in 2017 had similar demographics and the students in this paper were exposed to nearly the same course (any changes are described). Two instructors, one being the author, and both being faculty in the SoET, taught two cohorts each.

The reader should refer to Webster (2018) for additional details on the course (e.g., course learning outcome objectives, schedule, technology, curriculum, assessments, etc.) as this paper will provide only a synopsis and focuses on further describing the project and outcomes in detail. MET10200, is a 16-week, three-credit-hour CAD&D course that is a requirement for MET and MHET and an elective for ET students, respectively. MET10200 at Purdue Polytechnic New Albany consists of approximately 95% active learning, and it includes a combination of mini/bridging lectures (as needed), readings, group discussions, exams, assignments, and a team project. The smaller class size at Purdue Polytechnic New Albany—compared to the main campus—often allows for greater instructor involvement (i.e., coaching/mentoring) and more complex PBL, in terms of challenge, length, and authenticity.

The team project (along with its scope, requirements, deliverables, due dates, etc.) was introduced and teams formed by randomization during the first day of class. Class time during weeks 1–9 concentrated on learning the following curricula (i.e., course topics):

- History of engineering graphics
- Line conventions and lettering
- Orthographic and pictorial views
- Scales, fits, and fasteners
- Engineering drawing practices
- Parametric modeling
- Dimensioning and tolerancing (D&T)
    - General principles and conventions
    - Geometric Dimensioning & Tolerancing (GD&T) awareness
    - Rectangular coordinate dimensioning

It was during weeks 10–16 that teams were given the majority of class time to focus solely on the project, as the required course topics had been covered during weeks 1-9. Each team's objective was to design and build a catapult using only instructor-given materials, which did not include any commercial off-the-shelf (COTS) fasteners (e.g., screws, nuts) or adhesives that could replace the human thrower when playing cornhole. The cornhole catapult project was considered a semi-open design challenge due to the material restrictions; however, each team was encouraged and given the freedom to be creative and innovative when designing, building, and testing. Ultimately, teams from both sections would compete in a single elimination cornhole tournament on the last day of class. The author incorporated all project improvements identified after the 2017 case study (see Discussion Section). Additionally, starting in 2019, each team was asked to reflect on the project verbally in a video-taped interview. The interviews occurred in private during the tournament and were moderated by one of the instructors.

The Gold Standard PBL Model (see Figure 3) was not known about or used when the author originally created the team project or improved upon it following the 2017 case study. In accordance with the need to provide better descriptions and a more nuanced view of the active learning methods used in the classroom (Streveler & Menekse, 2017), and to explore the claim that the Gold Standard PBL Model promotes deeper learning and the development of critical KSAs (Larmer et al., 2015), the project in its current form has been cross-analyzed against the essential project design elements presented by the Gold Standard PBL Model (see Table 1). Identified gaps, weaknesses, and/or improvement areas will be discussed and addressed in future years.

Table 1: Project Design Elements: Adopted from (Buck Institute for Education, 2019; Larmer et al., 2015)

Design Element	Meaning	Application
Key knowledge, understanding, and success skills	Refers to the learning outcomes in terms of knowledge, skills, and abilities that are anticipated.	Refer to Webster (2018) for course learning outcome objectives. Students learn competencies such as design, problem solving, communication, and group/teamwork.
Challenging problem or question	The project is framed by a meaningful problem to be solved or a question to answer, at the appropriate level of challenge. Establishes a purpose for learning.	Teams design, build, test, and document a catapult using only instructor-given materials (which does not include any COTS fasteners and adhesives) to compete in a cornhole tournament with rules provided by the instructor.
Sustained inquiry	Students engage in a rigorous, extended process of posing questions, finding resources, and applying information.	Teams submit a research portfolio in week eight that shall contain at least background research (e.g., catapult types, pros, and cons), conceptual design(s), weighted decision matrix (or matrices), team meeting minutes/summaries. Teams primarily work on the project outside of the classroom during weeks 1–9 and inside the classroom during weeks 10–16.
Authenticity	The project involves real-world context, tasks and tools, quality standards, or impact, or the project speaks to personal concerns, interests, and issues in the students' lives.	Teams participate in a semi-open design challenge with a moderately-structured problem. The context of the project, the tasks completed, and the tools used are required in future upper-level courses and realistic to future career demands.
Student voice and choice	Students make some decisions about the project, including how they work and what they create.	Teams select any catapult type (e.g., mangonel, trebuchet, ballista) and have multiple decision opportunities concerning design (e.g., conceptual, preliminary, critical), manufacturing, testing, etc.
Reflection	Students and teachers reflect on the learning, the effectiveness of their inquiry and project activities, the quality of student work, plus obstacles that arise and strategies for overcoming them.	On the final day of class, students, as a team, reflect in a private video-recorded interview with the instructor(s) a. Also, students individually reflect during end-of-semester course and peer (i.e., project team members) evaluation surveys.
Critique and revision	Students give, receive, and apply feedback to improve their process and products.	Teams conduct an informal design review with the instructor in private during week 13. Teams receive feedback and critique from faculty, staff, peers, and the public during the tournament. Teams continually receive feedback internally and externally throughout the processes of designing, building, testing, and documenting the solution.
Public product	Students make their project work public by explaining, displaying and/or presenting it to audiences beyond the classroom.	Teams demonstrate their final catapults during a public tournament, which is part of a larger public showcase of student work across all grades.

Notes. [a]Only occurred in 2019

FINDINGS

Students at the end of each semester anonymously took a course evaluation survey created and circulated by Purdue University. The survey contained demographic-based questions, university-level questions about course and instructor satisfaction (see Table 2), course and lab-specific questions, and a written comments section (see Table 3)

Table 2: Course and Instructor Satisfaction

	Spring 2018 Grp Mdn (SD)		**Spring 2019** Grp Mdn (SD)	
	Instructor A	**Instructor B**	**Instructor A**	**Instructor B**
Questions	*n* = 21/30	*n* = 5/14	*n* = 13/15	*n* = 13/16
Overall, I would rate this course as	4.30 (.85)	4.00 (.89)	4.90 (.36)	4.60 (.63)
Overall, I would rate this instructor as	4.40 (1.11)	4.30 (.75)	4.90 (.36)	4.40 (.50)

Notes. *n* = number of respondents/possible number of respondents; 1 = very poor, 2 = poor, 3 = fair, 4 = good, and 5 = excellent; *Grp Mdn* = a grouped median measurement that is used to calculate the intention of most individuals who complete an evaluation and is a weighted average designed to remove undue influence from outliers.

Table 3: Course Evaluation Survey: Sampling of Student Comments

ID	Comments
1.	"For the Catapult project, how about we have to make two catapults, the first one is due at the mid-term, then the second is due at the end of the term, that way we can improve on the iteration, and learn from our mistakes."
2.	"…the randomization of teams for the project is misguided. If the random team concept will continue, my advice would be a thorough peer review of team members' performance at different points of the semester. I have been told this choice to have random team members is representative of the real world, and I completely agree. However, it is also of the real world for people to be held accountable by superiors."
3.	"Better materials for the project would be the biggest help for the course."
4.	"Groups are randomly assigned, but I feel as if there should be a competency requirement with designing."
5.	"My suggestion is for students to be tested how well they design and be able to demonstrate their abilities of what they can accomplish, just like taking a real job in the career field."
6.	"I really did not enjoy the catapult project. I understand how the project is very helpful for freshman to learn how to make technical drawings and get more experience in the shop. However, this project did not seem real-world applicable at all, and I did not have fun making our machine. To me, a valuable project has purpose and direct relation to something we would see in the field. I would recommend making the technical drawing projects based on the design challenges made in CGT 163. Or designing a more complicated machine as a whole class, rather than groups of 4. In the real world, most project teams consist of 8 or more people contributing."
7.	"This course is laid out very well to help push student towards self-motivation and good time management and has a final project that very strongly highlights the goals of the class."

Notes. Comments taken from all cohorts

Based on the self-reported data, on average and across all cohorts, the students believe that they had moderately to greatly improved their design (M = 3.19), problem-solving (M = 3.25), and group/teamwork competencies (M = 3.23), and slightly to moderately improved their communication competencies (M = 2.95), as result of taking the course (see Table 4).

Table 4: Classroom Activities and Outcomes: Competency Area

Competency Area	Spring 2018[a] *M (SD)* *n = 24/44*	Spring 2019[a] *M (SD)* *n = 18/31*	COMBINED *M (SD)* *N = 42/75*
Design			
a. Understanding of what engineers do in industry or as faculty members	3.21 (.96)	3.28 (.73)	3.24 (.87)
b. Understanding of engineering as a field that often involves non-technical considerations (e.g., economic, political, ethical, and/or social issues)	2.79 (1.00)	3.00 (.82)	2.88 (.93)
c. Knowledge and understanding of the language of design in engineering	3.29 (.93)	3.22 (.79)	3.26 (.87)
d. Knowledge and understanding of the process of design in engineering	3.29 (1.02)	3.28 (65)	3.29 (.88)
e. Your ability to do design	3.21 (.91)	3.39 (.76)	3.29 (.85)
Problem-Solving			
f. Your ability to solve an unstructured problem (that is, one for which no single "right" answer exists)	3.21 (.91)	3.28 (.56)	3.26 (.73)
g. Your ability to identify the knowledge, resources, and people needed to solve an unstructured problem	3.17 (.85)	3.17 (.50)	3.17 (.72)
h. Your ability to evaluate arguments and evidence so that the strengths and weaknesses of competing alternatives can be judged	3.25 (.78)	3.39 (.68)	3.31 (.74)
i. Your ability to apply an abstract concept or idea to a real problem or situation	3.13 (.93)	3.28 (.65)	3.19 (.82)
j. Your ability to divide unstructured problems into manageable components	3.21 (.96)	3.50 (.60)	3.33 (.84)
Communication			
k. Your ability to clearly describe a problem orally	2.88 (.88)	3.17 (.60)	3.00 (.79)
l. Your ability to clearly describe a problem in writing	2.83 (.85)	3.00 (.67)	2.90 (.78)
Group/Teamwork			
m. Your ability to develop ways to resolve conflict and reach agreement in a group	3.21 (.71)	3.22 (.63)	3.21 (.67)
n. Your ability to pay attention to the feelings of all group members	3.25 (.92)	3.33 (.67)	3.29 (.82)
o. Your ability to listen to the ideas of others with an open mind	3.21 (.91)	3.50 (.69)	3.33 (.84)
p. Your ability to work on collaborative projects as a member of a team	3.13 (.83)	3.39 (.68)	3.24 (.78)
q. Your ability to organize information into categories, distinctions, or frameworks that will aid comprehension	3.25 (.78)	3.67 (.58)	3.43 (.73)
r. Your ability to ask probing questions that clarify facts, concepts, or relationships	3.13 (.97)	3.33 (.82)	3.21 (.91)

s. After evaluating the alternatives generated, to develop a new alternative that combines the best qualities and avoids the disadvantages of the previous alternatives	3.13 (.93)	3.28 (.65)	3.19 (.82)
Other, Unscaled Items			
t. Your ability to develop several methods that might be used to solve an unstructured problem	3.17 (.75)	3.22 (.71)	3.19 (.73)
u. Your ability to identify the tasks needed to solve an unstructured problem	3.21 (.82)	3.50 (.60)	3.33 (.75)
v. Your ability to visualize what the product of a project would look like	3.13 (.93)	3.28 (.73)	3.19 (.85)
w. Your ability to weigh the pros and cons of possible solutions to a problem	3.17 (.75)	3.33 (.67)	3.24 (.72)
x. Your ability to figure out what changes are needed in prototypes so that the final engineering project meets design specifications	3.13 (.88)	3.44 (.68)	3.26 (.82)

Notes. n = number of respondents/possible number of respondents; 1 = none at all, 2 = a slight amount, 3 = a moderate amount, and 4 = a great deal; a two sections each year

DISCUSSION AND IMPLICATIONS

Based on students' self-reported satisfaction scores for the course and instructors (see Table 2), the author believes a variety of variables contributed to the score improvements from 2018 to 2019: instructors became more comfortable with the curriculum, discovered potential pitfalls for themselves and team success, optimized curricula for deeper learning, matured their mentoring/coaching competences, etc. Written student feedback (see Table 3) from each cohort was thoroughly analyzed each year in an attempt to identify project improvement areas. For example, after the 2017 tournament, the size and weight of the cornhole bags and the throwing distance were reduced, which produced a significant increase in scoring during the ensuing tournaments—so much so that future tournament games will be scored to 12 not 21, because games were taking too long to complete. The improvements have also resulted in the majority of teams choosing to construct smaller catapults. The smaller envelope sizes, better material utilization, and improved manufacturing lab equipment allowed teams to create multiple physical prototypes after weeks of digital design iterations. The concept of iterative design is fully representative of real-world practices and is also expected of students in upper level hands-on design, build, test, and document courses.

Starting after the 2017 tournament, the instructors decided to keep the top two or three catapults for display in the classroom. The idea was that current teams would use past years' catapults as design inspiration, learning tools, background research, etc. The instructors actually encouraged teams to visually inspect (i.e., touching was not allowed) the various functional elements of each and in combination with their own research, to create a unique catapult of their own. The type of catapult is generally limited to a mangonel, trebuchet, or ballista. However, each year, teams continually innovate and build a diverse pool of catapults (see Appendix).

Through observations, feedback (see Table 3), and cross-analysis of the Gold Standard PBL essential design elements (see Table 1), it can be concluded that additional project improvements are needed. First, the primary building material given to the teams in all three years (2017-2019) has been a sheet of sheathing plywood. However, due to manufacturing and quality variances in the material, the instructors have changed the sheet to tempered hardboard. In 2019 (i.e., the trial year), teams were given a sheet of both material types and all teams eventually constructed their final catapult using the tempered hardboard sheet only. Second, to further encourage earlier testing and design revisions, if needed, teams will have to upload a video demonstrating a successful loading and firing of their catapult approximately two weeks before the tournament. If successful, and no repairs, are needed, teams can spend the time eliminating throwing variance and documenting the design (i.e., technical drawing package). Third, an agreed-upon list of open-ended questions is needed for the team reflection interviews. The interviews conducted in 2019 were spontaneous in nature. However, the authors agree with the importance of reflection in PBL and want to ensure there is an opportunity to do so aside from the general course evaluation survey. To encourage open and honest feedback, the interviewer may also need to be someone other than a course instructor.

The communication competency area received the lowest average score (M = 2.95) across all four areas and was comprised of only two questions. Item k (your ability to clearly describe a problem orally) and item l (your ability to clearly describe a problem in writing) received similar scoring each year. However, the author expected to see much higher scores for written communication due to the research portfolio and technical drawing package requirements. Many of the research portfolio submissions were over 10 pages in length and the instructors provided detailed markups and feedback concerning technical writing best practices. Teams were also given the opportunity to receive additional points if portfolios were revised and resubmitted. Furthermore, each team was also required to submit a technical drawing package that communicated how to build, assemble, and inspect their catapult design. Often considered the language of engineering, technical drawings are the most widely used form of written language in engineering-related fields and some teams created over 30 dimensioned and toleranced technical drawings in accordance with (IAW) the American Society of Mechanical Engineers (ASME) Y14.100, Engineering Drawing Practices standard. However, based on the lower-than-expected item l score (M = 2.90), the author believes students do not view technical drawings as a strong form of written communication.

Item scores across all competency areas were similar to the 2017 case study (Webster, 2018). However, the increased average scores for item e (your ability to do design) in recent years is of interest. Originally, the author believed the lower-than-expected 2017 scores were in part due to the verb usage of do, which may have caused the question to be ambiguous and imply a need for higher-order thinking skills from students. This is due to the vertical movement on Bloom's Taxonomy from knowledge and comprehension to application with the action verb do (i.e., procedural knowledge, how to do something) (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956; Krathwohl, 2002).

Generalizations must be limited due to multiple factors, such as the inherent concerns with descriptive research (e.g., participants' truthfulness, researchers' bias, no manipulated variable) (Grand Canyon University, Center for Innovation in Research and Teaching, & McNabb, n.d.), and, furthermore, each cohort had a relatively small sample and homogenous demographics (Pawley, 2017). Additional limitations to note include the multiple uncontrollable variables between each cohort (e.g., different instructors, differing skill levels at entry, subjective grading of technical drawings, improved instruction over time), participants were not random, the use of indirect over direct assessment methods, and the author being an instructor of record and researcher. It should be noted that the classroom activities and outcomes survey was published and validated in 1998 (Bjorklund, Terenzini, Parente, & Cabrera, 1998; Terenzini, Cabrera, & Colbeck, 1999) and since then it has been used in multiple published studies (Schimmels, 2007; Strauss & Terenzini, 2005; Terenzini, Cabrera, Colbeck, Bjorklund, & Parente, 2001; Vavreck, Ferrara, Marra, & Bogue, 2008; Webster, 2017, 2018).

Descriptive research typically only describes a situation, subject, behavior, or phenomenon and is not directly used to discover inferences, make predictions, or establish causal relationships: it is naturally limited. The methodology has, however, led to future research questions in this context, such as what is the impact on ET students' competencies (1) as they progress up a design spine and/or through a plan of study, (2) if demographics were to be more diverse (i.e., other than young white males), and (3) if direct assessment methods are used. Future research is also needed to explore ET and applied engineering students' understanding of design, such as what is design, how does one do design, who does design, design process knowledge, etc.

CONCLUSION

In conclusion, the author hopes that by providing precise details on the course, curriculum, and instructional methods, other instructors may adopt the practices and the engineering, ET, and applied engineering research communities will be aided. The objectives of this descriptive research paper were to explore, through indirect assessments, how an introductory CAD&D course impacted ET students' (1) design, problem-solving, communication, and group/teamwork competencies, and (2) perceptions of the instructor and course, specifically the active learning instructional activities. Based on the students' self-reported results and observations, the author believes that ET students can gain important knowledge, skills, and abilities as early as freshman year from an introductory CAD&D course that uses the Gold Standard PBL model for a semi-open design challenge with a moderately-structured problem.

According to Webster, Dues, and Ottway (2018), the various instructional methods commonly used to teach CAD-based courses, including technical drawings, include (1) textbook, where students sequentially work through the chapters with the instructor available as needed, (2) Simon Says approach, where the instructor will execute a command at an instructors' station while students observe, followed by the students replicating the same action at their stations, and (3) self-created or online (e.g., e-book, video streaming, marketplace) material. All three techniques may include a level of active learning. However, learning is done on an individual basis. The team project described in this paper and in Webster (2018) is unique in that it aligns with the Gold Standard PBL Model, does not last days but, rather, spans the entire semester and requires high levels of collaboration between students and faculty. The author believes that the length and team elements of the project were the largest contributors to KSA gain and also indirectly promoted multiple PBL essential design elements (e.g., authenticity, sustained inquiry).

Finally, the cornhole catapult project, as described by this descriptive research, provides educators with a thoughtful, tested, and thorough team PBL example that can be adopted early in a design spine. The project provided students with opportunities to think deeply, solve challenging problems, work with others, and to learn how to manage personal learning, time, and tasks efficiently. Meanwhile, students also developed critical competencies, such as design, problem solving, communication, and group/teamwork that are required of 21st-century ET students and working professionals.

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Figure 4: 2019 Tournament Entry (1st Place)

Figure 5: 2019 Tournament Entry (2nd Place)

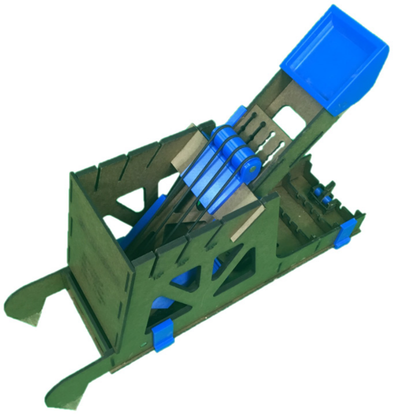

Figure 6: 2018 Tournament Entry

Figure 7: 2018 Tournament Entry (2nd Place)