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Industry Supplied CAD Curriculum and Team Project-Based Learning: Case Study on Developing Design, Problem-Solving, Communication, and Group Skills

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Abstract:

This case study investigates the extent to which industry supplied computer-aided design (CAD) curriculum and team project-based learning impacts undergraduate engineering technology students' engineering design, problem-solving, communication, and group participation skills. Evidence for the study comes from nine mechanical and one electrical engineering technology students enrolled in an upper level design course. Instructional materials included a SOLIDWORKS supplied CAD guide and a team project. Part three of the 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 as a result of taking the course. Results indicate that the sequential use of the industry supplied CAD curriculum and the team-based project will produce learning gains in vital engineering skills for engineering technology students. The results support the belief that active and collaborative instructional methods are more effective than the more conventional instructor-led lecture-based. The techniques used and the outcomes from have implications for not only curriculum but also ABET accreditation, who requires institutions to demonstrate that their graduates develop 11 competencies. Three of which are included in this case study. The intent of this paper is to provide a resource for engineering technology educators and administrators on classroom instructional materials that will produce outcomes aligned with ABET accreditation requirements.

Introduction

It has now been over twenty years since the ABET dramatically changed their outlook and criteria for evaluating engineering programs (Prados, Pterson, & Lattuca, 2005). It was in response to a call from engineering employers and visionary educational leaders to change the mold of the 21st century undergraduate engineer student. Industry wanted "college graduates who could work in teams and solve real world problems" (Cabrera, Colbeck, & Terenzini, 2001, p. 329).

> Employers increasingly emphasized that success as an engineer requires not only strong technical capability, but also skills in communication and persuasion, and ability to lead and work effectively as a part of a team, an understanding of the nontechnical forces that profoundly affect engineering decisions, and commitment to lifelong learning (Prados et al., 2005, p. 168).

Ultimately, ABET shifted its focus away from an emphasis on meeting curricular, resource, faculty, and facilities standards towards student learning outcomes and continuous improvement (Accreditation Board for Engineering and Technology & Engineering Technology Accreditation Commission, 2015, Strauss & Terenzini, 2005). ABET, who accredits programs rather than schools or departments, emphasized that undergraduate engineering students shall not only possess strong mathematical, scientific, and technical knowledge but also be able to effectively design, problem-solve, communicate, and work in teams (Accreditation Board for Engineering and Technology & Engineering Technology Accreditation Commission, 2015). A sample of the professional skills which are weaved in the 11 competencies that all programs must now demonstrate that their graduates have developed.

As the mold for an undergraduate engineering student began to change due to ABET's refocusing, the issue of how to help students develop the 11 competencies most effectively surfaced (Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001). Some believed that active and team-based instructional approaches would be more effective than conventional instructional methods (i.e. lectures/discussions) in helping students develop these vital engineering skills (Terenzini, Cabrera, Colbeck, Parente, et al., 2001). A theory in part based on the general idea that active involvement by students and collaborative learning (e.g. team-based learning, peer-learning, and peer tutorial) would produce higher levels of professional skill development. The body of research investigating how best to educate 21st century engineering technology students to meet ABET's 11 competencies has grown over the last two decades but opportunities to add to the body of knowledge are still present and needed (Bjorklund, Parente, & Sathianathan, 2004, Turner, 2015).

This paper describes a case study in which a small sample of senior engineering technology students were exposed to a design course that consisted of industry supplied curriculum (i.e. SOLIDWORKS guide) and a team project. In the context of this paper, industry supplied curriculum is defined as instructional material that was created and distributed by specific companies (e.g. Dassault Systèmes) from a particular field (e.g. computer-aided engineering). Initial motivation for the course design and investigation formulated from complaints expressed by past senior engineering technology students at Purdue Polytechnic New Albany during and after their senior capstones. This caused a faculty concern that the students were not fully prepared for senior capstones and ultimately were lacking skills, knowledge, and/or practice in the following areas.

- Engineering Design
    - Computer-Aided Design (CAD)
    - Engineering Drawing
    - Standards/Specifications
- Project Management
- Professional Competencies

The general opinion expressed by faculty and students to address these deficiencies, was a need for a course which would better prepare them for senior capstone. The hope for the course described in this case study is to grow engineering technology students' engineering design, problem-solving, communication, and group skills needed to be successful and excited about participating in a senior capstone sequence.

The purpose of the study was to investigate the relationship between instructional activities in an engineering technology classroom and students' self-reported skill development as a result of taking the course. For this case study, the following were the research questions:

- Are the students satisfied with the given industry supplied curriculum?
- Are the students satisfied with the team project?

- Which additional SOLIDWORKS topics/lessons do the students wish were included in the industry supplied curriculum?
- Which additional SOLIDWORKS functionality/tools do the students wish were included in the industry supplied curriculum?
- How does industry supplied curriculum and team project-based learning impact undergraduate engineering technology students'
    - engineering design skills
    - problem-solving skills
    - communication skills
    - group participation skills

Methodology

Participants
Ten undergraduate students (9 male) enrolled in MET302: CAD in the Enterprise, of which all were seniors (90+ credit hours). Nine students were majored in Mechanical Engineering Technology (MET) and one in Electrical Engineering Technology (EET). The purpose of the course was to provide intermediate to advance competencies in technical drawing, CAD, and design for manufacturing. All participants were registered Purdue University students.

Procedure and Setting
The three credit hour course took place in the spring 2016 academic semester at the Purdue Polytechnic New Albany campus in a typical CAD classroom/lab, containing desktop workstations (single monitors), white boards, projectors, and printers. The author was the professor of record and independently prepared the course. The course met twice a week for the first six weeks and as needed for the following 10 weeks. The 16 weeks were subdivided in the following categories:

- Weeks 1-6: Industry supplied curriculum
- Weeks 7-16: Team project-based learning

During weeks 1-6, the instructor utilized the mountainboard student guide (Dassault Systèmes, 2013b). Distributed online by Dassault Systèmes along with the accompanying mountainboard instructor guide (Dassault Systèmes, 2013a). All the lessons (i.e. 1-9) were assigned. After completing the guide, each student should have developed the skills needed to create 3D solid models and assemblies, fully define 2D dimensional drawings from 3D geometry, conduct simple static simulations, analyze motion, and clearly communicate their design intent with powerful visuals, such as detailed engineering drawings, animations, and photorealistic renderings. Typically, each week (two class periods) consisted of the following:

- Period 1:
    - Instructor presented the lesson(s) overview PowerPoint to the students.
    - Students were assigned to complete the lesson(s). The instructor emphasized following the guide with great detail and accuracy.

- Period 2:

- Class reviewed the previous lesson(s). Instructor displayed and discussed modeling practices/procedures for the corresponding models provided in the lesson(s).
- Instructor administered an online quiz in regard to that weeks' lesson(s)
- Students were assigned to complete the lesson(s).

During weeks 7-16, the instructor introduced a team project titled the mountainboard scope change project. The teams were presented with a fictional customer, who was a professional mountain boarder and sporting goods store owner. The customer asked each team to make the following changes (i.e. scope change) to the mountainboard which was previously produced:

- Increase product value (i.e. increase potential sales)
- Increase rider safety
- Increase rider stability (does not count towards increased safety)
- Increase manufacturability
- All drawings shall be IAW ASME Y14.100-2004
- Transition from purely mechanical to electromechanical (optional)

The objective of the project was to prepare students for industry-based design practices which generally occur prior to detailed prototyping and/or production manufacturing. The project is considered an open-ended challenge because each team was given the freedom to be creative and innovative in how they would meet the scope change requirements. Finally, each team was given a budget of $150 and tasked with delivering a mind map (review and final), preliminary design review (PDR), and critical design review (CDR) (see Figure 1).

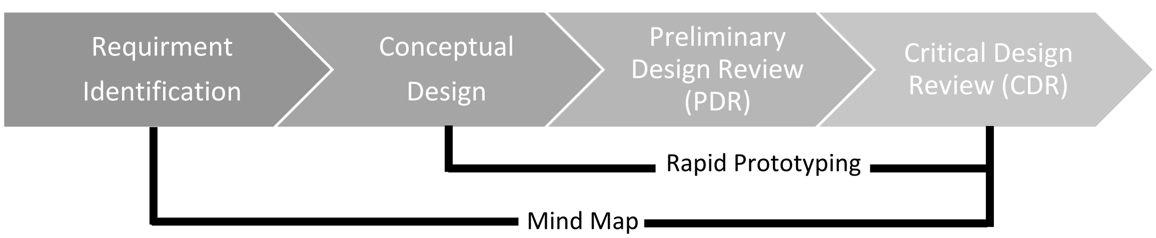

Figure 1. Mountainboard Scope Change Project Sequence

The mind map was a live working document that the team used to visually organize information, such as design breakdown, resource allocation, project scheduling, design goals, budgeting, etc. (see Figure 5). The mind mapping software used was Coggle (www.coggle.it), which provides online real-time collaboration. Teams shared their mind map with the professor, which allowed for real-time change notifications, commenting, and progress tracking.

Each team had to arrange a PDR and CDR with the professor, who was acting as the fictional customer. At each design review the teams were allowed 45 minutes to present, and the meeting location was a standard conference room to represent industry norms. At PDR teams were tasked with delivering a level 2 (i.e. developmental) Technical Data Package (TDP) with 3D digital models and associated drawings. At CDR the TDP was to be at level 3 (i.e. production). See Appendix for small sample of team submissions at CDR. Project nomenclature, steps, requirements, etc. were taken from MIL-STD-31000A, which is representative of common industry practice (Department of Defense, 2013). Brusse-Gendre (2002), gives the following descriptions for PDR and CDR:

> PDR. Design concepts are evaluated for feasibility, technical adequacy and general compliance with requirements, and the relative merits/weaknesses of different concepts are presented. Assumptions and calculations that led to conclusions are provided, and whenever possible, preliminary prototypes, mock-ups, sketches, models, and/or drawings are used to communicate the various concepts. The technical progress of the project is reviewed, as is the current and projected status of the budget and schedule. Potential risk items are highlighted and mitigation plans are evaluated. (p. 2)
>
> CDR. An intermediate design review that occurs after the detail design is complete, and prior to the fabrication of prototypes or pre-production models. This review is conducted to evaluate the design against the detailed requirements. It has many of the components as a PDR including the provision of assumptions and calculations used in the design, project progress and risk management. A production assessment is often included. (p. 3)

Assessment

Overall, the students were graded on a weighted scale for the semester (see Table 1). The professor used a self-created rubric to evaluate each team's PDR and CDR (see Figure 2).

Table 1. Course Evaluation

Category	Frequency (count)	Total Points Possible	Grade Weight (percent)
Participation/Attendance		10	5
Quizzes	7	70	22.5
Assignments	10	100	22.5
Team Project	1	35[1]	50

Notes. [1]Mind map review (5 points), mind map final (10 points), PDR (10 points), CDR (10 points)

	Levels of Achievement			
Criteria	Proficient	Emerging	Developing	Deficient
Graphical Presentation	Demonstrates high level of organization, balance, and audience engagement. The visual aides greatly enhance the presentation and never contain misspellings and grammatical errors. Presentation length was within the given time limits and a question/answer session was held. The correct PowerPoint template was used. Exceeds or meets project requirements for presentation.	Demonstrates moderate level of organization, balance, and audience engagement. The visual aides somewhat enhance the presentation and rarely contain misspellings and grammatical errors. Presentation length was within the given time limits and a question/answer session was held. The correct PowerPoint template was used. Meets project requirements for presentation.	Demonstrates low level of organization, balance, and audience engagement. The visual aides very little enhance the presentation and sometimes contain misspellings and grammatical errors. Presentation length was not within the given time limits and a question/answer session was not held. The incorrect PowerPoint template was used. Does no meet all project requirements for presentation.	Demonstrates no level of organization, balance, and audience engagement. The visual aides do not at all enhance the presentation and often contain misspellings and grammatical errors. Presentation length was not within the given time limits and a question/answer session was not held. The incorrect PowerPoint template was used. Does no meet project requirements for presentation.
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/or subtractive manufacturing. Physical prototype is complete and functional. Exceeds or meets project requirements for physical prototype.	Demonstrates moderate level of competency with additive and/or subtractive manufacturing. Physical prototype is complete and functional. Meets project requirements for physical prototype.	Demonstrates low level of competency with additive and/or subtractive manufacturing. Physical prototype is incomplete and nonfunctional. Does not meet project requirements for physical prototype.	Demonstrates no level of competency with additive and/or 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.

Figure 2. PDR and CDR Rubric

Data Source

At the end of the course, each student completed two online (Qualtrics) cross-sectional surveys. Each began with collecting student background and demographic characteristics. First, the mountainboard project survey was created by the instructor and consisted of 10 questions. On questions one and two students self-reported on their overall satisfaction with the industry supplied CAD guide and the team project by selecting a response on a five-point Likert scale (where 5 = extremely dissatisfied, 4 = somewhat dissatisfied, 3 = neither satisfied nor dissatisfied, 2 = somewhat satisfied, and 1 = extremely satisfied) that best reflected their perception (see Table 2). For questions three-eight and based on completing the mountainboard student guide, students self-reported on their skill development in the areas of CAD modeling, assembly, analysis, drawing, toolbox, and visualization (i.e. renderings and animations) by selecting a response on a five-point Likert scale (where 5 = much worse, 4 = somewhat worse, 3 = about the same, 2 = somewhat better, and 1 = much better) that best reflected their perception (see Table 3). Question nine asked students to select from a provided list any additional lessons/topics that they wished were included in the mountainboard guide (see Figure 3). Question ten asked students to rank (1 = most wanted to 10 = least wanted) any additional SOLIDWORK functionality/tools they wished were included (see Figure 4). Both lists were created by the instructor.

The second 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 instrument 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 4). It is described in detail by Terenzini, Cabrera, Colbeck, Bjorklund, and Parente (2001) and Terenzini, Cabrera, Colbeck, Parente, et al. (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), preformed a factor analysis on the original 27 survey items which produced four factors. 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 skill gains (see Table 4).

Results

Mountainboard Project Survey

Table 2. Industry Supplied Curriculum and Team Project Satisfaction

Item	Mean	Std. Deviation
Industry Supplied Curriculum	1.40	0.66
Team Project	1.20	0.16

Notes. 5 = extremely dissatisfied, 4 = somewhat dissatisfied, 3 = neither satisfied nor dissatisfied, 2 = somewhat satisfied, and 1 = extremely satisfied

Table 3. SOLIDWORKS/CAD Skill Development

Item	Mean	Std. Deviation
Modeling	1.50	0.67
Assembly	1.70	0.90
Analysis	1.80	0.60
Drawing	1.70	0.46
Renderings/Animations	1.60	0.66
Toolbox	2.30	0.64

Notes. 5 = much worse, 4 = somewhat worse, 3 = about the same, 2 = somewhat better, and 1 = much better

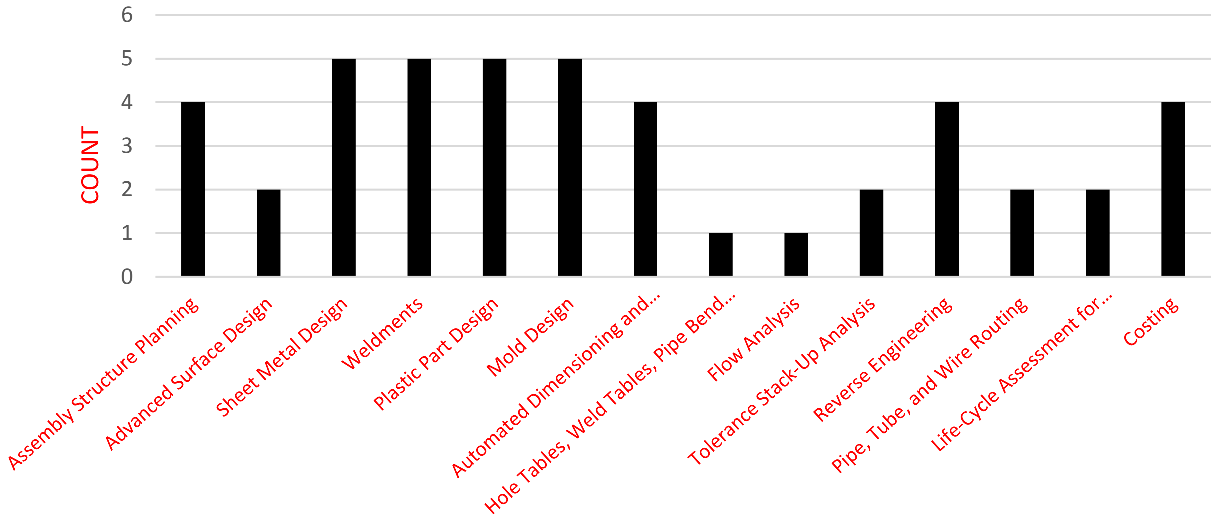

Figure 3. Additional SOLIDWORKS Topics/Lessons Frequency

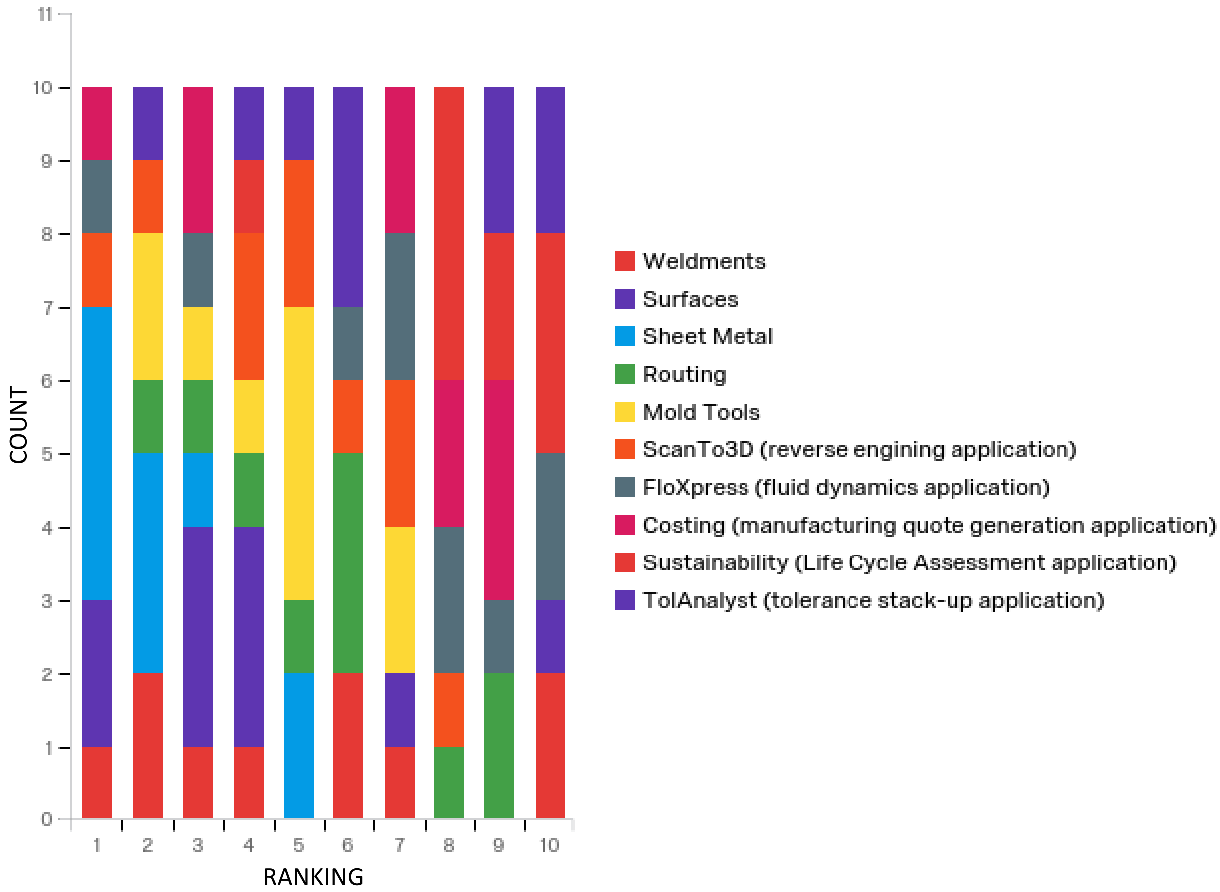

Figure 4. Additional SOLIDWORKS Functionality/Tools Frequency and Rankings

Classroom Activities and Outcomes Survey

Table 4. Course Related Skill Gains

Factor	**Mean**	**Std. Deviation**
Design Skills		
a. Understanding of what engineers “do” in industry or as faculty members	3.30	0.64
b. Understanding of engineering as a field that often involves non-technical considerations (e.g., economic, political, ethical, and/or social issues)	2.90	0.94
c. Knowledge and understanding of the language of design in engineering	3.60	0.49
d. Knowledge and understanding of the process of design in engineering	**3.70**	0.46
e. Your ability to “do” design	3.20	0.60
Problem-Solving Skills		
f. Your ability to solve an unstructured problem (that is, one for which no single “right” answer exists)	3.00	0.77
g. Your ability to identify the knowledge, resources, and people needed to solve an unstructured problem	3.00	0.63
h. Your ability to evaluate arguments and evidence so that the strengths and weaknesses of competing alternatives can be judged	2.90	0.70
i. Your ability to apply an abstract concept or idea to a real problem or situation	**3.20**	0.75
j. Your ability to divide unstructured problems into manageable components	3.00	0.89
Communication Skills		
k. Your ability to clearly describe a problem orally	**3.20**	0.75
l. Your ability to clearly describe a problem in writing	2.40	1.20
Group Skills		
m. Your ability to develop ways to resolve conflict and reach agreement in a group	3.20	0.60
n. Your ability to pay attention to the feelings of all group members	3.40	0.66
o. Your ability to listen to the ideas of others with an open mind	3.40	0.66
p. Your ability to work on collaborative projects as a member of a team	**3.50**	0.50
q. Your ability to organize information into categories, distinctions, or frameworks that will aid comprehension	3.20	0.87
r. Your ability to ask probing questions that clarify facts, concepts, or relationships	2.90	0.94
s. After evaluating the alternatives generated, to develop a new alternative that combines the best qualities and avoids the disadvantages of the previous alternatives	3.10	0.70
Other, Unscaled Items		

t.	Your ability to develop several methods that might be used to solve an unstructured problem	2.70	1.00
u.	Your ability to identify the tasks needed to solve an unstructured problem	2.80	0.75
v.	Your ability to visualize what the product of a project would look like	3.10	1.04
w.	Your ability to weigh the pros and cons of possible solutions to a problem	3.10	0.70
x.	Your ability to figure out what changes are needed in prototypes so that the final engineering project meets design specifications	3.10	0.70

Notes. 1 = none at all, 2 = a slight amount, 3 = a moderate amount, and 4 = a great deal

Discussion

90 percent and 100 percent of the students expressed satisfaction with the industry supplied CAD curriculum and instructor created team project respectively ($M < 2.00$). In general, the instructor saw positive reactions to the sequential tasks of completing the guide and project. The guide helped create an equal playing field in terms of students' CAD skills and knowledge needed to be successful for the project. Students often expressed excitement and enjoyment with the project. Some even proclaimed that even with the large time commitment required to meet project requirements, it was their only instructor assigned project that they had completely finished in school. MET302 is considered a design course and "the nature of design courses allows situations where faculty can interact more often with students than they do in lecture-driven courses and, therefore, have a greater effect on students' learning gains" (Bjorklund et al., 2004, p. 157). It has also been expressed that design cannot be taught using traditional lecture and discussion methods (Schon, 1990).

There are many educational resources (e.g. tutorials) available to teach CAD. However, many are written at a beginners level and/or do not explore the more advanced tools/functionality of the software. The 500-plus page mountainboard guide was different on both fronts. Initially, it looked very intimidating to the students but after completion they expressed gratitude for the comprehensiveness and cohesiveness of the guide. Each lesson built of the last and offered the students a glimpse of what a real world design project may look like. With that being said the students actually wished it offered even more. Sheet metal, plastic part, mold, and weldment design were tied for the most wanted additional/new lessons. When asked to rank a possible list of additional SOLIDWORKS tools/functionality they wished were include in the guide, sheet metal was the clear favorite with six first place rankings and all 10 students ranking it within the top 5.

The self-reported data clearly shows that the students believe they have made progress in a variety of learning and skill development areas as a result of taking the course. Industry supplied CAD curriculum and team project-based learning is shown to impact undergraduate engineering technology students' engineering design, problem-solving, communication, and group participation skills. The instructor considers both activities to be *active* learning and have positive implications for meeting some of ABET's 11 competencies.

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 et al., 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 small sample size so generalizability should be limited, but continued data collection will take place in the spring of 2017. Finally, more objective tests, such as standardized tests or demonstrations of skills are often favored over self-reports and could yield different results. However, research suggests that self-report measures of learning can be as valid as objective measures (Cabrera et al., 2001). Hayek, Carini, O'Day, and Kuh (2002), state that generally five conditions need to be met to be true:

1. The information requested is known to respondents
2. The questions are phrased clearly
3. The questions refer to recent activities
4. The respondents think the questions merit a serious and thoughtful response
5. Answering the questions does not threaten, embarrass, or violate the privacy of the respondent or encourage the respondent to respond in socially desirable ways

Conclusion

The findings indicate the instructional activities of using an industry supplied CAD guide and an open ended team based design challenge project will not only satisfy the students but produce gains in their design, problem-solving, communication, and group participation skills. All of which are competencies that ABET requires engineering technology graduates to possess. The results support the movement of more active and collaborative learning in the classrooms. However, it still remains that many faculty continue to rely on lecture as their primary, or even their only teaching practice. Based on this case study the author strongly supports the following claim by Terenzini, Cabrera, Colbeck, Parente, et al. (2001):

> Structuring classroom activities that promote gains in communication, design, and group skills are by their very nature complex. Developing exercises and assignments that call for design-based learning, coupled with the emphasis on constant feedback, will require specialized abilities and knowledge that will, in turn, require training or substantial experience for most faculty members. Strong commitment to faculty development will be needed on the part of engineering departments and colleges to facilitate the constant upgrading of critical teaching skills and techniques (p. 129).

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Appendix

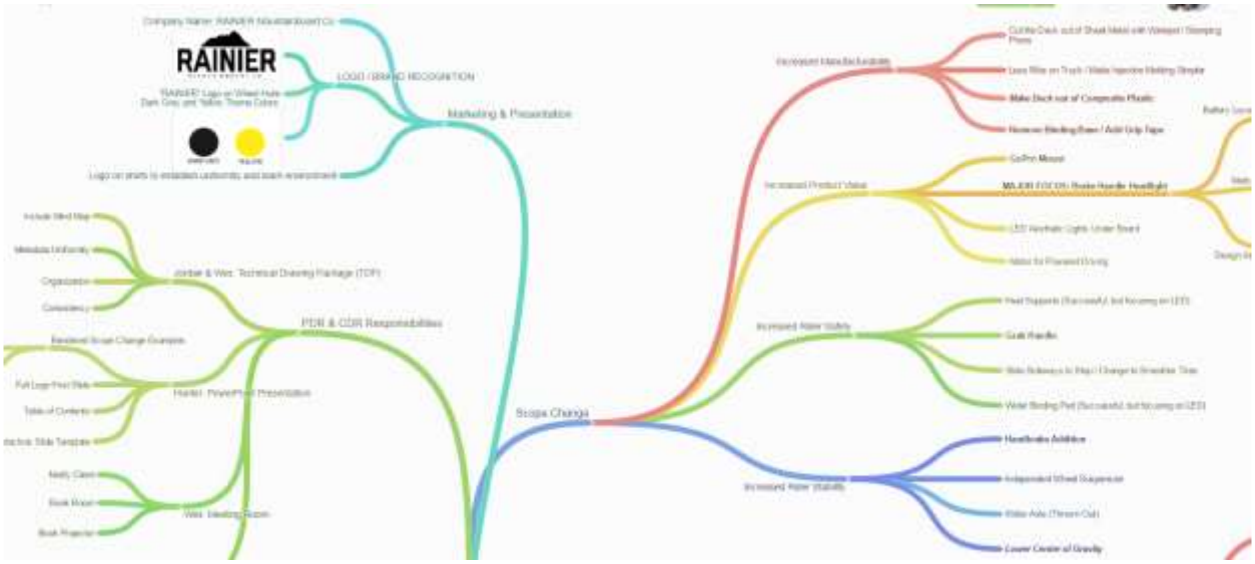

Figure 5. Mind Map Clipping

Figure 6. CDR Submission – CAD

Figure 7. CDR Submission – Prototype

Figure 8. CDR Submission – Rendering/Branding

Figure 9. CDR Submission – Rendering/Branding