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The Effects of Course Goals on Student Motivation in Computer-Aided Design Courses

Dr. Tyler Carter Kreipke CSC, University of Portland

Tyler Kreipke, CSC, received his Bachelor of Science from Rose-Hulman Institute of Technology in 2011, majoring in Biomedical Engineering with a concentration in Biomaterials and minoring in German. He completed his doctorate in Bioengineering from the University of Notre Dame in 2017, where his dissertation focused on bone mechanobiology. He completed his Master of Divinity at the University of Notre Dame in 2023, and was ordained to the Catholic priesthood as a member of the Congregation of Holy Cross in 2024. He now teaches mechanical engineering at the University of Portland in Oregon. His research interests include developing student self-efficacy and engagement in mechanical engineering, specifically in design and engineering graphics contexts.

Mr. Chris James Hainley Jr, University of Portland

C.J. Hainley is an Engineering Instructor at the University of Portland with over 15 years of combined experience in industry and academia. He specializes in CAD, manufacturing, and human-centered design, and directs student-led electric vehicle and UAV design competition projects. A former design engineer at ESCO Corporation and research fellow at Draper Laboratories, he holds an M.S. in Aeronautics and Astronautics from MIT and a B.S. in Mechanical Engineering from the University of Portland.

Dr. Joshua Gargac, Ohio Northern University

Joshua Gargac is an Associate Professor of Mechanical Engineering at Ohio Northern University.

Dr. Craig M. Goehler, University of Notre Dame

Dr. Goehler is a ”Triple Domer” in that he received all three of his degrees from the University of Notre Dame: BSME in 2002, MSME in 2004, and PhD in 2007 (all in the areas of mechanism/robot analysis and synthesis). After nearly a decade under the Dome, he took on a postdoctoral research associate role at the Rehabilitation Institute of Chicago where he discovered his love for bioengineering, specifically the application of mechanical engineering techniques to describe human movement. From 2009 until 2021, Dr. Goehler was a professor at Valparaiso University and finally returned home to take on a faculty position at Notre Dame in August 2021. He is extremely passionate about being an educator and truly believes that ”there is no such thing as a dumb question except for the one left unasked.”

Dr. Lynn Dudash, University of Mount Union

Lynn Dudash is an Assistant Professor of Biomedical Engineering at University of Mount Union.

Dr. Michael Foster, George Fox University

Michael Foster received a B.S. in engineering from Messiah College and M.S. and Ph.D. degrees in mechanical engineering from Drexel University. He is currently a Professor of mechanical engineering at George Fox University and the chair of the Dept. of Mechanical, Civil, and Biomedical Engineering.

Dr. Kayt Frisch, George Fox University

Dr. Frisch’s research helps students and professionals engage with data in meaningful and insightful ways. She specializes in data relating to creating student learning experiences, biomechanics, and large-scale time-series data analysis.

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Tyler C. Kreipke, CSC, PhD, Christopher J. Hainley, PE, Joshua Gargac, PhD, Craig M. Goehler, PhD, Lynn Dudash, PhD, Michael Foster, PhD, Kayt Frisch, PhD

Abstract
This work-in-progress (WIP) study seeks to describe and evaluate the effects of different course goals on student engagement and motivation in computer-aided design (CAD) courses. CAD courses are a mainstay of mechanical engineering education. In the pursuit of greater student engagement and learning, CAD instructors have employed a diversity of strategies and course goals. This study will focus on two particular course goals in CAD classes: industry certification and project-based learning. Study participants will be undergraduate students enrolled in CAD courses that pursue either industry certification with the Certified SolidWorks Associate/ Professional (CSWA/CSWP) certificate or a multiple-week open-ended design project as major components of the course.

This will be a mixed-methods study that collects data over the course of three semesters from five different institutions: two small private universities in the Pacific northwest, two small private midwestern universities, and one mid-sized private midwestern university. Students enrolled in the CAD courses at these universities will be asked to complete a questionnaire at the beginning of the semester measuring their interest in learning CAD, anticipated motivation to learn CAD, and prior exposure to CAD. A similar questionnaire will be administered at the end of the semester that will also ask them to reflect on how the course goals affected their engagement with the course. It is anticipated that industry-based certification will lead to greater increases in extrinsic motivation, while the open-ended projects will lead to greater increases in intrinsic motivation, as compared to a control group that employs neither of these goals.

1. Introduction

1.1. Student Motivation

Student engagement is a vital aspect of learning. Active and meaningful engagement on the part of the student with course material has been shown to benefit a number of desired student outcomes, including comprehension, retention, and application of material [1], [2], [3]. Meaningful engagement, in turn, has been shown to correlate with motivation [4], [5], [6]. Motivation can be described as the psychological impetus that drives goal-directed behavior [7], [8].

The self-determination theory (SDT) developed by Deci and Ryan proposes three basic categories of motivation: (1) intrinsic motivation, (2) extrinsic motivation, and (3) amotivation [9]. Intrinsic motivation describes when students seek to learn about a topic from an internal desire to do so. Here, students engage in the learning process as an end in and of itself, out of a sense of curiosity or an enjoyment of the subject itself. Extrinsic motivation is characterized as students seeking understanding not as an end in itself, but in service of some further goal or value. This type motivation can be externally imposed, as through a rewards- or demands-based system, or it can be internalized and/or brought into congruence with the student's own values to varying degrees. Amotivation is understood as a lack of action toward a goal, or a lack of meaningful engagement with goal-based actions [10], [11]. Within a classroom context, autonomous motivation (i.e. intrinsic motivation and highly internalized extrinsic motivation) tends to correlate positively with meaningful cognitive engagement and positive student outcomes, followed by internalized extrinsic motivation, while externally imposed motivation and amotivation does not [4], [11].

It is important for educators in engineering to consider that motivation is not a static characteristic [7], [8], [12], [13]. Studies have shown that student motivation can be influenced by a number of different factors, such as time [13], [14], the prevailing emphases of the students' learning environment (e.g. understanding or grades), [7], [15] and mastery experiences [5]. Of particular importance for this study, Stolk, Zastavker, and Gross have shown that different pedagogical strategies, such as with class style and course assignments can influence student motivation [8]. The dynamic nature of motivation, coupled with its correlation with positive student outcomes, recommends its development as a point of focus for engineering educators.

1.2. "Industry Certification" and Project-Based Learning in Computer-Aided Design

This study is particularly interested in student motivation as related to course goals and assignments in computer-aided design (CAD). CAD courses are a foundational component of mechanical engineering curriculum, which teach students skillsets that can be used in later coursework and in industry to design and fabricate physical components and devices. Instructors have used a variety of pedagogical strategies to foster the development of these skillsets through engagement with course material. This has, in part, consisted of the incorporation of different assignment types within their courses. This study will examine the effects on student motivation of two prevalent assignment types: "industry certification" and project-based learning.

Several CAD software packages offer "certifications" for the completion of tests that they have developed, such as with the Certified SolidWorks Associate/Professional (CSWA/CSWP) certifications. These "non-conforming professional certifications", as labeled by Webster and Ottway, do not meet the standards of certifications or licenses as detailed by Workcred [16], but instead are a recognition from the software developer that a certain level of proficiency has been reached with their CAD program. For this study, they will be referred to as "industry certifications" or simply "certifications". Webster and Ottway have performed a series of studies examining the merits of such nonconforming certificates in industry, and have suggested that their primary benefit may be for students by helping to validate students' knowledge and skills, improve their confidence, and strengthen their resumes to increase marketability [16], [17], [18], [19].

These reasons, among others, have led some CAD instructors to include the attainment of these certificates as part of their coursework. The tests provide a good benchmark for a basic skillset with CAD proficiency [18], and the skills required to receive the certification are directly based on proper use of appropriate functions of the program to build component models in CAD programs. Many instructors may see, therefore, that they provide a fitting assessment of student skills, while also offering additional benefits in the students' formation as engineers and in job searches. However, few studies to date have directly examined the effects of these certificates on student motivation towards CAD work. They may indeed provide extra incentive to drive student engagement, or they may present as an externally imposed motivation, and thus not correlate with increases in desired forms of student motivation and engagement.

Project-based learning is also a common method employed by CAD instructors to promote student engagement. Project-based learning has long been recognized as a form of active learning, and the incorporation of projects as a main course goal or assignment has been shown to increase motivation within the classroom [8], [20], [21]. According to SDT, a certain level of autonomy is needed to foster intrinsic motivation [9]. Open-ended design projects provide opportunities for students to engage their autonomy and creativity in generating design solutions, and can fit well within the scope of CAD courses. Project-based learning can thus provide an attractive means of developing student motivation and engagement, especially when incorporating open-ended design projects.

2. Methods

This mixed-methods, multi-institutional study seeks to better understand the influence of course assignments and goals on student motivation towards CAD. The study has been approved by the Institutional Review Boards at the institutions where the study has taken place.

2.1. Study Institutions and Timeline

Upon completion of this study, data will have been collected at five different universities. Two universities are small, private institutions in the Pacific Northwest, two are small private universities in the Midwest, and one is a medium-sized private university in the Midwest. Upon completion of the study, the medium-sized midwestern institution will have collected data over three semesters, the northwestern universities will have collected data over two semesters, and two of the small midwestern and northwestern universities will have collected data over one semester.

2.2. Participant Selection

Study participants are selected from students enrolled in CAD/computer-aided engineering courses at the different universities participating in this study. The courses in this study are 200- and 300-level courses. Participation in the study is voluntary. Identifying information is collected so that changes in motivation throughout the semester can be quantified more precisely, but responses are not opened until students have completed the courses.

2.3. Course Assignments & Goals at Institutions in the Study

The courses for this study are separated into two categories based on whether a course at a given institution incorporates industry certification examinations or an open-ended project as major course components. In particular, the certificates pursued in the courses in this study are the CSWA or the CSWP. A third group that uses neither certifications nor open-ended projects will also be included when the study is complete.

The small universities in the Pacific northwest incorporate certification as a significant part of the course. One of the small midwestern universities also utilizes industry certification as a course goal, while the other implements standard examinations and assignments as the evaluative assignments for student performance. The medium-sized midwestern university incorporates a multi-week open-ended design project that requires students to generate design ideas, model one of their ideas, and then construct a physical prototype of their design.

2.4. Study Design and Research Questions

For the portion of the study that has been completed, participants were asked to complete a questionnaire regarding their motivation towards their coursework/general CAD-work at the beginning and end of the courses in which they were enrolled. The questionnaires consisted of both 5-point Likert scale questions and open-ended questions. The surveys that were administered can be found in Appendix 1.

2.5. Statistical Analysis

Statistical analysis was performed using Matlab (Mathworks). Data were analyzed using non-parametric tests due to the non-continuous distribution of response values for the surveys. Statistical significance was set at a p-value of 0.05, although a p-value of $0.05 \leq p \leq 0.10$ was considered as trending towards significance. For all figures, bars indicate mean Likert-scale values for associated responses. Error bars represent 1 standard deviation. Single asterisks are used to indicate differences with a p-value of $0.05 \leq p \leq 0.10$, and double asterisks are used to indicate differences of $p \leq 0.05$.

2.6. Qualitative Analysis

Open ended responses were analyzed using the CoPilot – GPT – 4 AI software package (Microsoft). The software was asked to analyze major themes from the responses from the beginning and end of the semester surveys. The results from the AI software were corroborated by manual evaluation of the comments, and individual representative comments were selected by the authors.

3. Results

3.1. Study Participation

Data have been collected from two of the five institutions to date. One of the small northwestern and one of the small midwestern institutions have collected data from one semester, and the medium-sized midwestern university has collected data from two semesters.

130 students were enrolled in the courses across all the universities that have collected data, with 92 from the medium-sized midwestern university and 38 students from the Pacific northwestern university. At the medium-sized midwestern university, 72 (78%) students responded to the initial survey and 33 (36%) to the final survey, with 30 (33%) students completing both surveys. At the northwestern university, 35 (92%) students responded to the initial survey, 20 (53%) to the final survey, and 18 (47%) to both surveys.

Data were included for changes in motivation levels in the course only for students who responded at both time points of the survey. Open-ended responses or responses to how the course goals specifically affected motivation were included in the analysis even if the respondent only responded at one of the time points.

36 substantive responses were provided for the open-ended responses asking students about their motivation for the course/CAD-work at the beginning of the semester, and 20 were provided at the end of the semester.

3.2. Student Interest & Effort Over the Course of the Semester
In the initial survey, students in the certification group indicated an average interest level in the course of 4.88 $\pm$ 0.33 on a 5-point Likert scale, with 1 being 'Very Disinterested' and 5 being 'Very Interested.' Students in the project group indicated an average initial interest in the course of 4.50 $\pm$ 0.68 on the same Likert scale. The Mann-Whitney test revealed a significant difference in the starting interest level of the two groups ($p<0.05$).

The certification group experienced an average change in interest of -0.12 $\pm$ 0.49 over the course of the semester, and the project group reported an average change of -0.10 $\pm$ 0.67, based on paired data. A Wilcoxon Signed-Rank test revealed that neither of these changes were statistically significant from their initial paired values (p>0.10), as shown in Figure 1. Direct comparison of the change in interest level over the course of the semester did not reveal a significant difference between the groups, according the Mann-Whitney test (p>0.10).

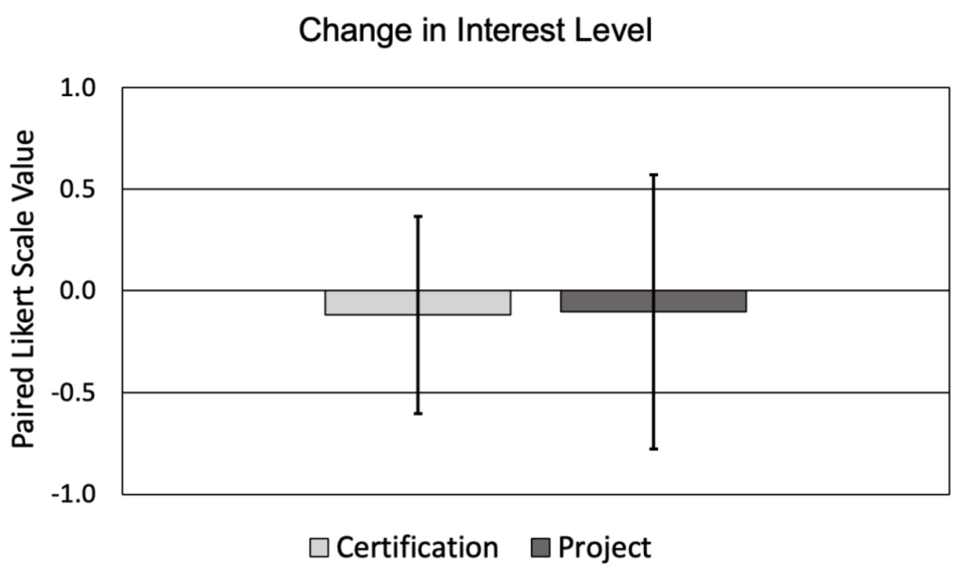

Figure 1. Paired statistical tests did not detect significant changes in student interest in CAD-based classes or work from their initial paired values throughout the course of the semester for either group. There were no significant differences in the change in interest between groups (n_{cert}=18, n_{proj}=30).

In the initial survey, the certification group indicated an average willed effort level of 4.56 $\pm$ 0.86 on a 5-point Likert scale, with 1 being 'No Effort' and 5 being 'Extensive Effort.' The project group indicated an average willed effort level of 4.20 $\pm$ 0.61 on the same Likert scale. Mann-Whitney analysis detected a significant difference in the starting willed effort level between the two groups (p<0.05).

The certification group reported an average change in willed effort level of 0.06 ± 0.64 over the course of the semester, with the project group reporting an average change of -0.20 ± 0.61, based on paired data. A Wilcoxon Signed-Rank test did not reveal a significant change in willed effort level in the certification group from their starting level (*p*>0.10), although the response trended towards significance for the project group (*p*=0.092). Direct comparison with the Mann-Whitney test of the change in willed effort level over the course of the semester between groups did not reveal any significant differences between the groups (*p*>0.10), as seen in Figure 2.

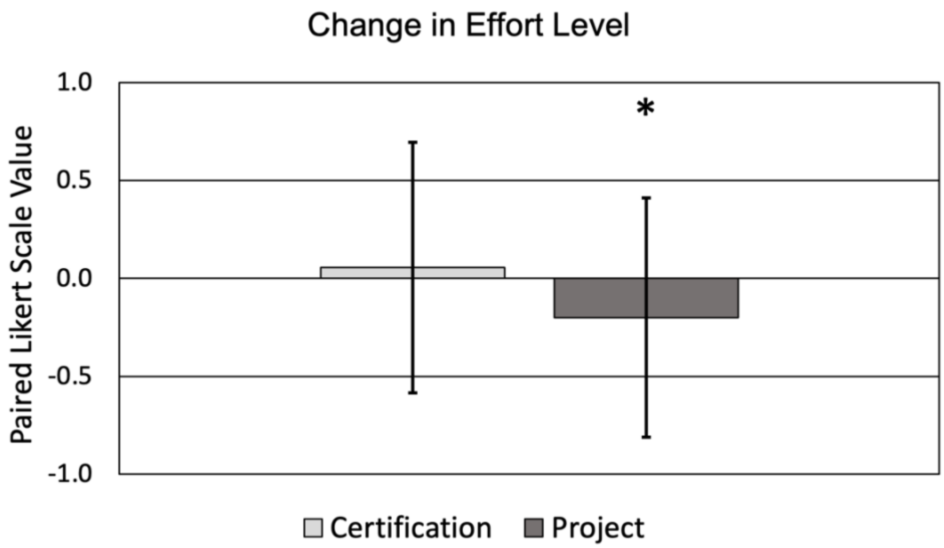

Figure 2. Paired statistical tests did not detect significant changes in student effort for CAD-based classes or work from their initial values throughout the course of the semester for either group, although the change trended towards significance for the project group (*p*=0.092). The difference in change in effort level between the groups was not found as significantly different (p>0.10, n_{cert}=18, n_{proj}=30).

3.3. Course Goal Effects on Student Interest & Effort

At the end of the semester, students in the certification group responded with an average level of 4.40 ± 0.82 for the effect of course goal (i.e. the certification or the project) on their interest in the course/CAD-work on a 5-point Likert scale, with 1 indicating that the course goal 'Greatly Decreased Interest' and 5 indicating that it 'Greatly Increased Interest'. Students in the project group showed an average level of 4.03 ± 0.68 for the effect of course goal on interest. No significant difference was found between the groups regarding the effect of course goal on interest according to analysis with the Mann-Whitney test, but the difference trended towards significance (*p*=0.052) in favor of the certification having a more positive effect on interest level, as seen in Figure 3.

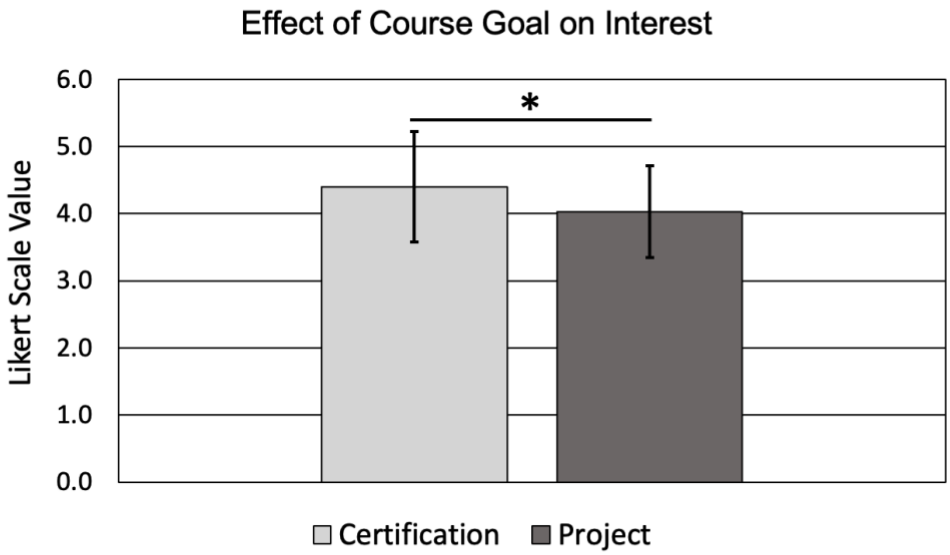

Figure 3. Each course goal had a positive perceived influence on student interest in CAD. No statistically significant difference was detected between the groups for the effects of course goal on interest, although the difference trended towards significance (p=0.052, n_{cert}=20, n_{proj}=33).

Students in the certification group indicated an average level of 4.45 $\pm$ 0.76 for the effect of course goal on willed effort level on a 5-point Likert scale, with 1 corresponding to the course goal 'Greatly Decreasing Effort' and 5 corresponding to 'Greatly Increasing Effort'. Students in the project group responded with an average level of 4.30 $\pm$ 0.64 for the course goal's effect on willed effort based on the same Likert scale. The difference between the groups for the effect of course goal on willed effort was not significant according to the Mann-Whitney test (p>0.10), as shown in Figure 4.

Figure 4. Each course goal had a positive perceived influence on willed level of effort towards CAD. No statistically significant difference on willed effort level was detected between the two groups based on course goal (p>0.10 n_{cert}=20, n_{proj}=33).

4. Discussion

4.1. Analysis of Initial Quantitative Results

Survey responses revealed high initial levels of interest towards CAD for both groups, with mean response values falling between ‘Somewhat Interested’ and ‘Very Interested’. Similarly, reported levels of effort that students were willing to put into the courses were, on average, between ‘Significant Effort’ and ‘Extensive Effort’. This suggests that many students may come into CAD-based courses with strong levels of both intrinsic motivation, corresponding to interest level, and extrinsic motivation, corresponding to willed effort level. Although the initial levels of interest and effort were higher in the certification group ($p<0.05$), neither interest nor willed effort level significantly decreased from their initial values over the course the semester in either group, although the decrease in the project group’s effort level trended towards significance ($p=0.092$). This would suggest that students’ experiences with the material in these classes continued to engage their interest and elicit effort from them over time.

Both types of course goals were perceived by students to have a positive effect on their interest and effort in the course. Mean student response values for both the certification and the open-ended design project corresponded with the course goals ‘Somewhat Increasing Interest’, and ‘Somewhat Increasing Effort’. Comparison between the groups suggests that the certification may be able to better stimulate student interest than the open-ended project. However, it is important to note that this result only trended towards significance ($p=0.052$), and may be related to the certification group having a higher level of interest and effort at the start of the course than the project group. Still, this is an interesting result, as it was expected that the open-ended project would stimulate student interest to a greater extent than industry certification, and that industry certification would increase willed effort more than the open-ended project. It was reasoned that the open-ended project was more likely to engage students’ creativity and autonomy, which has been found to correlate with intrinsic motivation [9]. Conversely, it was expected that industry certification would have led to greater increases in willed effort level, as this goal was less open-ended, but more directly tied to potential career advancement. This meant that it could be viewed more readily as a means to an end, which is more associated with extrinsic motivation [9], [10]. However, neither of these outcomes were supported by the results of this study. The certification’s effect of promoting interest may suggest that students had a strongly identified or integrated motivation towards the certification exam. The test may serve as a means to an end, but students may have identified with the end that it serves, or integrated the value of its associated skillsets to such an extent that the certification does not come as an external imposition, but something that the students readily engage with based on personal reasons/values. The certification test may also be seen as a potential mastery experience that can provide external validation of the students’ acquired skills.

4.2. Analysis of Initial Qualitative Results

Open-ended responses tended to reflect a high level of motivation on the part of the students, although there were a number of different sources that influenced student interest and engagement. A number of students expressed an inherent interest in developing CAD skills, particularly as a way to engage in a hands-on creative process that bring designs to life. CAD’s ability to facilitate the realization of ideas was mentioned by several students, as seen in the following comments:

"My main motivation is that learning CAD opens up the doors to creativity and unlocks possibilities that may have not been easily achieved if it were not for 3D modeling. It also helps with visualization which is good for knowing how a product will look in the real world."

Open-ended design projects may lend themselves more readily to improving engagement from these types of students. However, if students are not interested in the project prompt, it may detract from engagement, as noted by one of the students from the project group:

"I'm interested in CAD and in this course but am more moderately interested than I possibly might be depending on what the projects are. That could be more or less interested depending on the projects."

Many students' interest and efforts were driven by the translatability of CAD to industry. Several students indicated a desire to go into engineering fields that utilize CAD heavily, such as the automotive industry. Many expressed a desire to improve their proficiency in CAD so that it could be utilized in engineering clubs, personal projects, or their long-term careers. In the short-term, it was noted by several students that the course, and the certification in particular, was viewed as a way to improve their marketability in searching for jobs/internships. One student reflected on the role of the certification, saying:

"I was very motivated to learn CAD and become proficient in order to pass the CSWA. I was motivated because it is an actual certification I could put on a resume."

However, it is important to note that this is based on the student's own perceptions and assumptions. Another student was curious to know how the industry itself viewed the CSWA:

"I would like to know how companies or recruiters treat job applications that have CSWA vs CSWP… I think that would potentially change my involvement or engagement with the course"

Still, it would seem as though projects and certifications can both provide an impetus to stretch students in a subject where there appears to be an already high level of engagement. Reflecting on their experience with the certification exam, one student noted that:

"I think that, while [the certification] increased the pressure, it pushed me to want to do better."

And a student looking back on the effects of the project on their effort level in the class said:

"The project made me work in this class."

4.3. Strengths and Limitations of the Study

A primary strength of the study is its incorporation of multiple different institutions across multiple semesters. This helps provide a more generalizable set of data for other CAD-classes. However, there are still a number of limitations that should be considered when transferring its findings to other studies. The study did not incorporate data from any large or public universities, and sample sizes were relatively small from the institutions where data were collected. In addition, the motivation assessment instrument was not a validated instrument, such as the SIMS [22] or the AMS [10]. Participation in the study was also voluntary, which may have skewed responses, as more engaged students may have been more likely to respond.

5. Conclusion

5.1. Major Trends & Points of Interest

The incorporation of open-ended projects and industry certification can be beneficial to student motivation in CAD courses. High levels of interest and effort were reported by the students at the beginning of the semester, and their experiences in the course did not cause a significant change in their interest and willed effort towards CAD-based work. In addition, the incorporation of both of these major assignments/course goals were perceived by students to increase both their interest and their willed effort level. However, the certification showed a greater positive effect on student interest that trended towards significance when compared to the open-ended project. This may indicate that incorporating a certification may be a good way to improve student engagement in CAD courses. However, because both types of course goals/assignments were perceived by students as beneficial to student engagement, if there are legitimate reasons for preferring an open-ended project over a certification related to desired course outcomes, the incorporation of projects can still be an effective way to promote student engagement with CAD. For example, projects might still be preferred in courses that seek to incorporate aspects of the design process.

The high motivation levels that students expressed may themselves be an important point of interest from this study as well, irrespective of course goals/assignments. Based on these results, students seem well disposed towards CAD-based work due to a number of different reasons. This may have broader implications for mechanical engineering curricula. The high levels of motivation towards CAD-based work shown in this study suggest that other mechanical engineering courses may benefit from the incorporation of CAD-based elements into their coursework. This may promote student interest and effort by providing students an opportunity to engage the creative and hands-on/visual aspects of CAD, or through helping them to continue to develop a skillset that is readily perceived to translate to more industrial applications.

5.2. Future Directions

As mentioned, this study is intended to incorporate more data from more institutions by the time of its completion. Of particular importance in this will be the inclusion of a group that utilizes neither industry certifications nor multi-week projects/assignments to serve as a potential baseline group for student motivation. It is anticipated that the final results of the study will help instructors to foster student engagement with CAD-based work in academic contexts.

Once all the intended data from the study have been collected and analyzed, there are still a number of further studies that can help understand student motivation towards CAD. For example, this study focused primarily on mechanical engineering students utilizing 3D modeling software packages like SolidWorks. However, industry certification's effects could also be tracked in civil engineering contexts, where industry certificates are also available with programs like AutoCAD. Or, it may be interesting to understand more about the effects of project-based learning on motivation. Future studies could examine student motivation in response to different types of projects, such as close-ended projects, where students model larger and more complex, but pre-determined, components, or open-ended projects that don't incorporate physical builds of their designed prototypes. It would also be interesting to explore if there is any effect of industry certification on student identification as an engineer, which could in turn affect retention, both as a mastery experience and as an external validation of their engineering skills [23], [24]. Lastly, because student engagement is aimed ultimately at developing proficiency with course content, a study evaluating how different course goals develop students' CAD skillsets could provide valuable insight.

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Appendix 1. Study Questionnaires

Table 1. Questions in the Beginning of Semester Survey

1. How interested are you in this course? (5-point Likert)
2. How much effort are you willing to put into this course? (5-point Likert)
3. How much experience do you have with CAD from before this course? (5-point Likert)
4. If applicable, what were the sources of your experience with CAD before this course? (Open-ended)
5. Do you have any comments you'd like to share about your interest/motivation related to this course/CAD work in general? (Open-ended)

Table 2. Questions in the End of Semester Survey

1. How interested are you in CAD work (for school or otherwise)? (5-point Likert)
2. How much effort are you willing to put into CAD work (for school or otherwise)? (5-point Likert)
3. How did the incorporation of the CSWA certification/project/course assignments affect your interest in the course? (Open-ended)
4. How did the incorporation of the CSWA certification/project/course assignments affect your effort in the course? (Open-ended)
5. Do you have any comments you'd like to share about your interest/motivation related to this course/CAD work in general? (Open-ended)