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Investigating Students' Development of Computer-Aided Design Self-Efficacy: An Analysis of Pre-Course CAD Exposure

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With the increasing demand for new and innovative technologies, engineers are called on to be at the forefront of designing new products. As a result, undergraduate engineering programs must equip students with both technical skills and internal beliefs that they are capable of success in the profession post-graduation. For mechanical engineers, knowledge of computer-aided design (CAD) software is an invaluable skill in order to contribute to product development in a wide variety of industries. However, students at the undergraduate level enter university with varying levels of knowledge and beliefs in their capabilities of using CAD software. Therefore, there is currently a lack of research investigating how students develop self-efficacy in relation to CAD prior to their undergraduate degree.

As there currently does not exist a validated scale to measure CAD self-efficacy, in this paper, we explore the related concepts of undergraduate engineering students' initial 3D Modeling and Engineering Design self-efficacy before formal CAD instruction at the university level. Bandura's Theory of Self-Efficacy suggests there are four main sources of self-efficacy: mastery experiences, social persuasion, vicarious experiences and physiological states [1]. Therefore, we aim to answer the question: "What prior CAD learning experiences influence undergraduate engineering students' self-efficacy with 3D Modeling and Engineering Design?" [2]. Adapting validated measurement tools for 3D Modeling and Engineering Design self-efficacy, we surveyed second-year mechanical engineering students to target beginner CAD users regarding their prior instruction and knowledge of CAD as well as their perceived self-efficacy in these areas [3]–[6].

Hierarchical multiple regression was used to analyze various reported levels of pre-course CAD exposure and test if they predict students' 3D Modeling and Engineering Design self-efficacy [7]. The results indicate that students' use of *video tutorials* and *personal projects* to learn CAD software is a significant predictor $(p < .01)$ of their 3D Modeling self-efficacy. Our findings did not discover any of our survey's forms of CAD exposure to be a significant predictor of Engineering Design self-efficacy.

These research findings provide a deeper understanding of the experiences that assist students in developing self-efficacy and familiarity with technical software in the pre- and early stages of their undergraduate degree [8]. The intention is to inform educators about how they can design an effective CAD curriculum accommodating students of all skill sets and to provide the foundation for developing and validating a CAD self-efficacy scale. Future work will focus on the implications of blended and project-based learning settings on students' development of 3D Modeling self-efficacy based on the post-course survey. As a result of this research, students will be able to maximize their learning and become better prepared for upper-year undergraduate studies and their careers in industry as mechanical design engineers [8].

Keywords: self-efficacy, computer-aided design (CAD), three-dimensional modeling, engineering design

1.0 Introduction

In our fast-paced world, the demand for innovation indicates the need for well-trained engineers, equipped with the technical skills and confidence to design products efficiently. Computer-aided design (CAD) software is a modern tool that enables engineers to design complex systems, through the creation of three-dimensional (3D) models. CAD is integrated broadly into engineering curriculums across various institutions [9]. To be accepted into an engineering program, there is emphasis placed on students' development of a strong skillset in mathematics and sciences at the secondary school level [10]. It can be argued that knowledge of CAD software and 3D modeling techniques are equally important skills for young engineers to develop due to their practicality and use in a variety of industries [9]. However, not all secondary schools offer computer and technology-based courses, let alone explicit CAD instruction. As a result, there is a phenomenon that students at the undergraduate level enter university with varying levels of knowledge and beliefs in their capabilities of using CAD software. As an individual's self-efficacy and beliefs regarding their academic pursuits greatly impact their achievements [11] it is critical for educators to gain a deeper understanding of students' CAD self-efficacy to foster an environment that supports all students and is conducive to their development of technical skills.

Self-efficacy or the belief in one's capabilities [1] is known to "influence the courses of action people choose to pursue, the challenges and goals they set for themselves and their commitment to them" [12, p. 309]. To assess a person's perceived self-efficacy within a particular area or context, Bandura created the *Guide for Constructing Self-Efficacy Scales* which suggests that self-efficacy scales should be customized to a domain [12]. Prior work in engineering education has considered the development and validation of tools to measure perceived self-efficacy focused on specific skills necessary in the field of engineering [5]. However, there currently does not exist a validated tool to measure students' self-efficacy regarding their perceived CAD skills.

We turned to literature to discover validated self-efficacy concepts within the domain of engineering that we believe are related to the development of CAD self-efficacy. Therefore, we explore students' 3D Modeling and Engineering Design self-efficacy using pre-existing, validated self-efficacy scales [3]–[6]. Adopting these measurement tools, we collected 140 survey responses from mechanical engineering students enrolled in a second-year project-based design course.

This work aims to further understand the forms of pre-course exposure that lead to the development of 3D Modeling and Engineering Design self-efficacy [8]. In a similar approach to Schar et al., students' learning experiences were considered as predictor variables of self-efficacy [2]. Gender identity was introduced as a control variable within the analysis due to prior work suggesting that male students often self-report a higher self-efficacy in skills related to engineering [2], [5], [10]. The results of the study indicate that the prior experiences better predict 3D Modeling self-efficacy, providing a basis for learning experiences to integrate into future CAD curriculum development.

2.0 Background

This research focuses on measuring the initial self-efficacy of undergraduate students in 3D Modeling and Engineering Design and pre-course learning experiences that contribute to their self-efficacy in this context [2].

2.1 Theoretical Framework: Bandura's Sources of Self-Efficacy Beliefs

The concept of self-efficacy was proposed by psychologist Albert Bandura, who stated that "perceived self-efficacy refers to beliefs in one's capabilities to organize and execute the courses of action required to manage prospective situations" [1, p. 2] and that "efficacy beliefs influence how people think, feel, motivate themselves and act" [1, p. 2]. Bandura suggests there are four main sources of self-efficacy: mastery experiences, social persuasion, vicarious experiences and physiological states [1]. Self-efficacy has been studied broadly in educational development, concerning students' persistence, motivation to learn and academic performance [11]. It is hypothesized that "students with a high sense of efficacy for accomplishing an educational task will participate more readily, work harder, and persist longer when they encounter difficulties than those who doubt their capabilities" [11, p. 204]. Therefore, Bandura's four sources of self-efficacy provide the theoretical framework for exploring related concepts to students' CAD self-efficacy.

2.2 Dependent Variables: 3D Modeling and Engineering Design Self-Efficacy

Within the context of engineering education, self-efficacy has been measured in a variety of domains including general engineering [5] and innovation [2], [13] in addition to specific skills like engineering tasks [2] and design [4], [5]. However, there has been limited research dedicated to studying the development and measurement of students' 3D Modeling self-efficacy.

Kelly and Denson designed and validated an eight-item 3D Modeling self-efficacy scale intended to measure high school students' 3D Modeling self-efficacy [3]. "Each item uses a seven-point Likert-type scale from 'highest level of agreement' to 'lowest level of agreement'" [3, p. 45]. Similarly, Carberry et al. validated a skill-specific scale to measure students' Engineering Design self-efficacy [4]. As a result, Mamaril et al. adapted items from Carberry et al. [4] in their validation study to assess how various forms of engineering skill-specific self-efficacy predict GPA and intention to persist in the field [5]. In addition, Mamaril et al. [5] also used a scale item from Schubert et al. and their study assessing students' ability to learn and apply the engineering design process [6]. As prior research demonstrates that skill-specific scales can be adapted into new studies [5], we implemented all items of Kelly and Denson's 3D Modeling self-efficacy scale [3] and four out of five items of Mamaril's Engineering Design self-efficacy scale [5] within our survey and the items are listed in the Appendix.

2.3 Control Variable: Gender Identity

Literature has demonstrated that gender has an influence on students' perceived self-efficacy within the context of engineering and STEM [2], [10], [13], [14] and therefore was included as a control in the analysis. Marra et al. conducted a study across five American institutions to analyze women students' engineering self-efficacy [10]. Relating to Bandura [1], it was mentioned that women consider vicarious experiences and social persuasion as the most important to their development of self-efficacy, whereas men place a greater emphasis on mastery experiences [10]. Their study demonstrated that women experience "a lack of inclusion in the environments in which they study engineering” [10, p. 34]. This lack of inclusion can be viewed as social persuasion, which therefore can impact women students’ self-efficacy [10]. Kolker explored the effect of STEM extracurricular clubs dedicated solely to women on high school girls’ self-efficacy [14]. They concluded that all-girls clubs promote and foster a sense of belonging for women, positively impacting their self-efficacy [14]. Therefore, we are curious to investigate if there is a negative or no correlation between students of the gender minority and their perceived self-efficacy regarding their 3D Modeling and Engineering Design skills.

2.4 Independent Variables: CAD Learning Experiences

The independent variables considered in this study are a variety of experiences by which students learn CAD software before enrollment in the course and commencing their undergraduate studies. While there are many possible ways for students to learn CAD before course enrolment, we discuss six interesting educational methods.

Prior work has focused on the prediction of students’ self-efficacy as a result of their learning experiences [2] and participation in extracurricular activities [2], [13]. Schar et al. aimed to discover the learning experiences of engineering students that correlate to the development of innovation and engineering task self-efficacy [2]. Using the Pratt ‘product measure’ approach [2], all 39 learning experiences were narrowed to include only the top 15 predictor variables. Undergraduate coursework in technical topics such as the theory of design and prototyping proved to be statistically significant predictors of engineering task self-efficacy [2], which inspired our independent variables of *explicit instruction* and *used in a previous course (but not directly taught)*.

The use of videos in an educational setting has demonstrated a number of benefits including increased understanding of course content [15], flexibility over the learning environment and accommodations for busy schedules [16]. Fuqua et al. discuss the creation of an online video tutorial library by studying its effects on student learning in a mechanical engineering undergraduate program [15]. They claim that “supplemental videos are an intervention used successfully by engineering programs, and previous research demonstrates improvement in student knowledge and performance” [15, p. 5]. Delaviz and Ramsay explore the implementation of short topic YouTube videos with high production quality in a first-year materials science course [17]. The results demonstrated that nearly three-quarters of students preferred the videos to a traditional lecture recording as their short duration and use of multiple camera angles appeared more engaging [17]. As a result of positive perception towards platforms like YouTube enabling access to a variety of educational resources (including CAD software resources) from virtually any device [17], we introduced the independent variables of *free online courses* and *video tutorials* into the analysis.

Although mastery experiences are proven to be the strongest indicator of one’s perceived self-efficacy [1], vicarious experiences demonstrate immense value in developing self-efficacy towards new or challenging tasks, particularly, by witnessing another individual of similar background [10]. Therefore, we considered the CAD learning experience *taught by family/friends* to be a vicarious experience and a potential predictor of 3D Modeling and Engineering Design self-efficacy.

Lastly, we include the variable of *personal projects* as students are often more engaged as a result of personal interest in a particular engineering-related topic or field [18]. Literature focused on CAD curriculum development emphasizes that students desire practical skills that they can apply in an industry setting as an engineer [9]. However, students may leave their courses with only working knowledge of the software interface, rather than a deeper understanding of strategic methods by which the tool can be used within the design process [19]. As *personal projects* give students the autonomy to apply their knowledge of CAD and gain hands-on experience, they are hypothesized to provide the foundation for the development of self-efficacy.

Therefore, we identify *explicit instruction in a previous university/college level course, used in a previous university/college level course (but not directly taught)*, *free online courses, video tutorials, taught by family/friends* and used the software in *personal projects* as methods for learning CAD that we consider as independent variables, in addition to including *gender identity* as a control variable.

3.0 Objectives and Research Questions

The objectives of this research study are to discover correlations between students' pre-course CAD experiences and their self-reported 3D Modeling and Engineering Design self-efficacy scores, considering their gender identity [2]. We further aim to identify the most common resources that students use to gain experience with CAD software before formal CAD instruction in university. This led to the development of two research questions to be addressed in the study.

Research Question 1 (RQ1): Is there a difference in 3D Modeling and Engineering Design self-efficacy between students compared by gender?

Research Question 2 (RQ2): What prior CAD learning experiences predict students' 3D Modeling and Engineering Design self-efficacy?

4.0 Methods

4.1 Data Collection

In the Fall of 2023, we administered a pre- and post-project survey to second-year mechanical engineering undergraduate students currently enrolled in a mechanical engineering design course at a research-intensive university in Canada. This course was specifically of interest because it represents the first opportunity for undergraduate mechanical engineering students to receive formal instruction of CAD software at the university level (as CAD is not presented in the first-year curriculum at this institution). The surveys were administered in a paper format with the self-efficacy scales adapted from Kelly and Denson [3] and Mamaril et al. [5]. The dependent variable of 3D Modeling self-efficacy was measured using a seven-point Likert-scale [3] and Engineering Design self-efficacy with a six-point Likert-scale [5]. Additionally, the survey asked respondents to rate their level of experience with CAD software before taking the course and to indicate how they gained previous exposure to the software.

For this study, as we are curious about how students' pre-course experiences contribute to their self-efficacy, only the pre-project survey results were considered, with the post-project survey to be analyzed in a future study. From the pre-survey, there were a total of 140 responses collected. After cleaning the data and removing invalid responses (i.e. responses with 3D Modeling self-efficacy, Engineering Design self-efficacy or gender identity left blank), there were 131 responses included in the sample.

4.2 Analysis Method

To analyze the relationship among variables, we first compute the descriptive statistics and the Pearson correlation matrix for the dataset. We follow a similar approach to Deng et al. through the use of hierarchical multiple regression analysis [7] and Schar et al. to examine the prediction of self-efficacy (dependent variables) as a result of learning experiences (independent variables) [2].

The self-efficacy data was treated as continuous to conduct the regression in Python to address RQ1 and RQ2 [2]. There were a total of seven independent variables which were converted from categorical data into quantitative (binary) data, making hierarchical regression a suitable approach as opposed to multiple logistic regression (where the categorical variables are treated as the dependent variables of the study) [2].

5.0 Results

Table 1 contains summary statistics of the dataset, including the sample demographics ($n = 131$). Students were asked to self-report which term best describes their gender identity. Two students selected non-binary, one selected genderfluid, and four preferred not to answer. These responses were categorized with the 50 students who identified themselves as a woman, to derive a binary variable for the analysis (*Gender Minority = 0, Man = 1*). The sample consisted of 43.5% of students identifying within the gender minority (not men) and 56.5% of students identifying as a man.

Many of the engineering students surveyed have no experience using CAD software (31.3%) or consider themselves beginners (41.2%), with intermediate and advanced users representing approximately one-quarter of the sample (27.4%). This is in contrast to computer confidence, where three-quarters of students reported intermediate confidence (72.5%) and few students mentioned none (4.6%). Lastly, students with any prior experience using CAD software were asked to indicate how they gained previous experience. The most popular response was video tutorials (34.4%), followed by personal projects (21.4%) and explicit instruction (13.7%).

Table 2 contains the mean and standard deviations for 3D Modeling and Engineering Design self-efficacy scores related to the total sample and based on students' gender identity and self-reported CAD experience level [2]. There is also an increasing trend of average 3D Modeling self-efficacy scores with more advanced users, however, intermediate CAD users reported the highest average Engineering Design self-efficacy scores.

Table 3 displays the Pearson correlation matrix between all variables. None of the independent variables demonstrate a significant correlation (>.5) to 3D Modeling or Engineering Design self-efficacy. However, *video tutorials* (0.38) demonstrate the highest correlation to 3D Modeling self-efficacy among all variables and *personal projects* (.12) for Engineering Design self-efficacy.

Table 1. Summary Statistics and Sample Demographics.

Variable	Percentage of Responses
Gender Identity	
Man	56.5
Gender Minority	43.5
Race/Ethno-cultural	
Non-Minority	18.3
Minority	81.7
Computer Confidence	
Beginner	14.5
Intermediate	72.5
Expert	8.4
None	4.6
CAD Experience Level	
No Experience	31.3
Beginner	41.2
Intermediate	22.1
Advanced	5.3
*CAD Experience**	
Explicit Instruction in a Previous University/College Course	13.7
Free Online Courses	13.0
Personal Projects	21.4
Taught by Family/Friends	13.0
Use in Previous University/College Course (But Not Taught)	9.2
Video Tutorials	34.4

**Note. Percentages were considered based on the total sample population (n = 131). CAD Experiences do not sum to 100% as respondents had the option to select multiple CAD Experiences.*

Table 2. Mean and Standard Deviation of Self-Efficacy Data.

		3D Modeling Self-Efficacy		**Engineering Design Self-Efficacy**	
Sample	n	$\bar{x}$	σ	$\bar{x}$	σ
Total	131	3.92	1.29	4.31	0.88
Gender Identity					
Man	74	4.09	1.33	4.38	0.82
Gender Minority	57	3.70	1.22	4.21	0.94
CAD Experience Level					
No Experience	41	2.95	0.90	4.03	0.80
Beginner	54	3.87	1.08	4.31	0.94
Intermediate	29	4.96	1.05	4.67	0.82
Advanced	7	5.64	0.39	4.35	0.54

Table 3. Pearson Correlation Matrix (*n = 131*).

	Variables	1	2	3	4	5	6	7	8
1	*Gender Identity*								
2	*Explicit Instruction*	-.19							
3	*Free Online Courses*	.20	-.02						
4	*Personal Projects*	.04	.06	.24					
5	*Taught by Family/Friends*	-.03	.04	.12	.13				
6	*Use In Course*	-.09	.18	.11	.22	.11			
7	*Video Tutorials*	.02	.08	.15	.25	.25	.22		
8	*3D Modeling Self-Efficacy*	.15	.14	.24	.36	.17	.19	.38	
9	*Eng. Design Self-Efficacy*	.09	-.03	.08	.19	.11	.12	.11	.38

5.1 Predicting 3D Modeling and Engineering Design Self-Efficacy via Hierarchical Regression

To address RQ1, a simple linear regression analysis was used to analyze if *gender identity* (*Gender Minority = 0, Man = 1*) is a significant variable within both models and contributes to students' initial 3D Modeling or Engineering Design self-efficacy. The results of Model 1 in Tables 4 and 5 demonstrate that gender is not a significant predictor of either form of self-efficacy.

Considering RQ2, hierarchical regression was performed with prior CAD experiences as predictor variables of self-efficacy [2], [7]. *Gender identity* was considered the control variable within the analysis to examine only the effects of the CAD learning experiences. The predictor variables were sequentially added into the model [7] based on the descending order of the highest correlation to 3D Modeling or Engineering Design self-efficacy within the Pearson correlation matrix (Table 3). Therefore, *video tutorials* were introduced first for 3D Modeling self-efficacy and *personal projects* for Engineering Design self-efficacy.

In Table 4, there was increasing predictability of 3D Modeling self-efficacy from Models 1 to 4, with a slight decrease when introducing the variables *used in a previous course* and *taught by family/friends* in Models 5 and 6 [7]. Model 7 includes all predictor variables for 3D Modeling self-efficacy with an overall model fit of $R^2 = 0.269$. Therefore, the proportion of 3D Modeling self-efficacy variance explained by the model is 26.9%. *Video tutorials* and *personal projects* were the two variables that proved to be statistically significant predictors of 3D Modeling self-efficacy ($p < .01$). Removing all statistically insignificant ($p \geq .05$) and control variables [7], model 8 concludes that the prediction of 3D Modeling self-efficacy can be represented by *video tutorials* ($p < .001$) and *personal projects* ($p < .01$) with a 21.8% variance.

Table 5 lists the hierarchical regression results for the prediction of Engineering Design self-efficacy. Model 2 demonstrated *personal projects* to be statistically significant ($p < .05$), but the variable becomes insignificant with the addition of each predictor variable (models 3 to 7). Therefore, we cannot conclude that the prior CAD learning experiences are a significant predictor of Engineering Design self-efficacy, and deem the results to be null findings.

Table 4. Regression Coefficients of Predictor Variables for 3D Modeling Self-Efficacy.

Variables	1	2	3	4	5	6	7	8
Constant	3.70 ***	3.40 ***	3.25 ***	3.25 ***	3.23 ***	3.21 ***	3.14 ***	3.44 ***
Gender Identity	.39	.37	.34	.29	.31	.32	.37	
Video Tutorials		1.02 ***	.83 ***	.80 ***	.77 **	.73 **	.72 **	.83 ***
Personal Projects			.87 **	.80 **	.76 **	.75 **	.74 **	.89 **
Free Online Tutorials				.42	.40	.38	.39	
Use in Course					.34	.32	.24	
Taught by Family/Friends						.22	.21	
Explicit Instruction							.46	
R^2	.023	.164	.236	.247	.252	.255	.269	.218
Adjusted R^2	.015	.151	.218	.223	.222	.219	.227	.206
F-statistic	3.00	12.6 ***	13.1 ***	10.3 ***	8.42 ***	7.08 ***	6.47 ***	17.9 ***

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 5. Regression Coefficients of Predictor Variables for Engineering Design Self-Efficacy.

Variables	1	2	3	4	5	6	7
Constant	4.21 ***	4.14 ***	4.12 ***	4.09 ***	4.07 ***	4.07 ***	4.09 ***
Gender Identity	.16	.15	.16	.16	.16	.16	0.15
Personal Projects		.39 *	.34	.32	.31	.31	.31
Use in Course			.27	.24	.23	.23	.25
Video Tutorials				.11	.08	.08	.08
Taught by Family/Friends					.20	.20	.20
Free Online Courses						.01	.00
Explicit Instruction							-0.10
R^2	.008	.041	.048	.052	.057	.057	.059
Adjusted R^2	.001	.026	.026	0.22	.019	.011	.005
F-statistic	1.07	2.74	2.16	1.72	1.51	1.25	1.09

Note. * $p < .05$, ** $p < .01$, *** $p < .001$.

6.0 Discussion & Future Work

This study aims to contribute to a growing body of literature on engineering skill-specific self-efficacy measures and form a basis for understanding how the assessment of differences in self-efficacy can inform educators in better supporting individuals with diverse skill sets using technical software. Based on our findings, we discuss various curricular interventions that can be implemented in engineering design courses to ensure students are developing CAD self-efficacy and maximizing their learning [9].

The findings from the linear regression analysis did not prove *gender identity* to be a predictor of 3D Modeling or Engineering Design self-efficacy. This is inconsistent with prior studies in which identifying as a *Man* proved to be a significant predictor [2] or highly correlated to self-efficacy in the domain of engineering [5]. In recent years, much attention has been placed on increasing representation and recruitment of women in applied sciences and engineering, examples of which include: hiring more women faculty members [10] and creating STEM clubs in high schools for woman-identifying students [14]. All-girl STEM extracurriculars have enabled woman-identifying students to become more resilient to gender biases and stereotypes, in addition to collaborating with like-minded individuals [14]. Also, our sample contained 43.5% of respondents identifying within the Gender Minority, allowing students to be around a large proportion of non-man-identifying individuals. Therefore, the recent shift in the culture [10] with accepting women in male-dominated careers may have provided the foundation for increased development of self-efficacy for women in engineering, and partially explain our lack of evidence of a difference.

As technological devices and online instruction have become increasingly more prevalent in academic settings, undergraduate students of this generation may exhibit different learning styles [17], which could impact their development of CAD self-efficacy. As *video tutorials* proved significant to the development of 3D Modeling self-efficacy, this study demonstrated the need for more online learning material or integrating blended learning [17] into CAD classrooms. As mentioned in the background, the video repository introduced by Fuqua et al. was overall well-received, increasing students' confidence in challenging course material and providing flexibility for students with different learning needs and commitments [15]. As CAD is primarily a single-user software tool and blended learning is known to promote learner autonomy [15], we believe that adding supplemental videos into CAD curriculum could positively impact students' CAD self-efficacy.

Personal projects are another form of CAD learning experiences that promote independent work and hands-on exposure. Although *personal projects* are completed on a student's own time outside of a course, their significance to the development of 3D Modeling self-efficacy suggests CAD courses may benefit from including more project-based work. Therefore, instructors could consider approaching engineering design or CAD courses through a Project-Based Learning (PBL) setting in the early undergraduate years [20]. Students can apply their CAD skills by completing an individual or team-based project (similar to Capstone Design) with only guidance provided by the course instructor rather than traditional instruction [20]. As the criteria of PBL is that the projects be student-driven and realistic, this environment can assist in fostering critical thinking [20] and provide students with the experiential and practical learning opportunities they desire [9] for the development of CAD self-efficacy.

The hierarchical regression analysis did not demonstrate any of the CAD learning experiences to be statistically significant to the development of Engineering Design self-efficacy. This contrasts with what we might initially expect, based on Carberry et al.'s assertion that engineering design self-efficacy is highly dependent on engineering experiences [4]. However, similar to Schar et al. our predictor variables do not encompass all possible CAD learning experiences, let alone engineering learning experiences [2]. Therefore, future work should consider including new predictor variables [2] as the current CAD learning experiences did not appear as effective as intended.

Since only the pre-project survey data was analyzed in this paper, a future study will consider whether students develop 3D Modeling self-efficacy during the second-year mechanical engineering design course by considering the post-project survey results. This study demonstrated that *personal projects* are important for students' initial 3D Modeling self-efficacy. We are curious to examine if a PBL environment contributed to students' self-efficacy through the completion of a team-based CAD project and how the implications of this learning experience can inform us about CAD self-efficacy.

7.0 Limitations

For the hierarchical regression analysis, students' *gender identity* was coded as a binary variable (*Gender Minority = 0, Man = 1*) to examine its influence on 3D Modeling and Engineering Design self-efficacy. However, this simplification may not fully encapsulate the lived experiences of students, how they engage with their prior learning and use of CAD software.

The independent variables considered in this study also pose limitations, in that we only considered six prior learning experiences of CAD software. Similar to Dungs et al. the survey did not collect information on students' engagement within their courses (for the variables of *explicit instruction* and *used in a previous university/college level course*) or the duration of time spent using these resources to become familiar with CAD [13]. Therefore, students may have developed 3D Modeling and Engineering Design self-efficacy through different experiences or other mediums that were not listed in the survey [2], [13].

8.0 Conclusion

This paper aims to further understand learning experiences as predictors of students' CAD self-efficacy through the related constructs of 3D Modeling and Engineering Design self-efficacy [2]. *Gender identity* proved to be an insignificant predictor variable despite men self-reporting higher average scores for 3D Modeling and Engineering Design self-efficacy. As mentioned, this could be a result of the progressive environment of increasingly accepting more women into engineering [10] and the large proportion of students in our sample identifying within the gender minority. The results demonstrated that the two CAD learning experiences of *video tutorials* and *personal projects* contribute to students' 3D Modeling self-efficacy, however, we were unable to conclude that they were beneficial for students' Engineering Design self-efficacy. Consequently, we suggest engineering educators consider the approaches of blended [15] or Project-Based Learning [20] environments to accommodate students with diverse backgrounds and needs when learning technical software like CAD. Overall, this study forms a basis for future research regarding engineering skill-specific self-efficacy measurement and the implications of team-based project work on the development of CAD self-efficacy.

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Appendix

Pre-Survey Questions

Questions
Gender Identity - Please indicate which term best describes your gender identity.
Genderfluid
Genderqueer
Man (cis, trans)
Nonbinary
Questioning
Two-Spirit
Woman (cis, trans)
Prefer not to answer
How did you gain your previous experience with CAD software, if any?
Explicit Instruction in a Previous University/College Course
Use in a Previous University/College Level Course (But Not Directly Taught)
Free Online Courses
Video Tutorials (e.g. YouTube Videos)
Taught by Family/Friends
Used the Software in Personal Projects
N/A - No Experience
Other (Please Specify)

Pre-Survey Adapted Self-Efficacy Scale Items

Item
3D Modeling Self-Efficacy Scale - Adapted from Kelly and Denson [3]
I feel that I am good at visualizing/ manipulating 3D objects in space.
I have confidence in my ability to model 3D objects using computers.
I am confident enough in my 3D modeling to help others model 3D objects.
I am good at finding creative ways to model 3D objects.
I believe I have the talent to do well in 3D modeling.
I feel comfortable using 3D modeling software.
I feel confident in my ability to create 3D objects in a variety of ways.
I feel I can communicate 3D objects to other peers.
Engineering Design Self-Efficacy Scale - Adapted from Mamaril et al. [5]
I can identify a design need.
I can develop design solutions.
I can evaluate a design.
I can recognize changes needed for a design solution to work.