Impact of Student Motivation and Confidence in a First-Year Hackathon Project

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Abstract

Universities are increasingly implementing design courses at the first-year level in Science, Technology, Engineering, and Mathematics (STEM) disciplines to expose students to design competencies early in their degree programs. These courses are typically deemed "cornerstone design," or "cornerstone" for short, and aid as an introduction for first-year students to engineering design. Outside of the formal design or theoretical concepts required by the students in these courses, they also teach competencies such as multidisciplinary teamwork, time management, and professional skills that are required of them entering the industry post-graduation. Cornerstone can consist of a single semester, two semesters, or a quarterly project, depending on the institution. At a primarily undergraduate, STEM-focused university, the cornerstone course teaches design and STEM principles and culminates in an interdisciplinary hackathon experience. The hackathon format allows for an early college career experience for students to apply knowledge, foster teamwork, and develop design skills through innovative solution generation.

The study examines the impact of prior experiences and major choice on a student's self-assessed motivation, confidence, success, and anxiety before and after participation in this cornerstone hackathon. In this preliminary investigation, the participation of first-year STEM students in a six-hour hackathon event was examined. Additionally, the students' K-12 experiences, demographics, and pre- and post-event self-assessed factors were gathered to investigate the influence of demographics and prior experiences on the self-assessed factors. The project is labeled a hackathon because it involves problem-focused tasks assigned to student participants and necessitates a diverse range of STEM skills to achieve a successful project outcome and provide a positive learning experience for students.

The study results indicate statistically significant increases in the students' confidence and success through the course. Additionally, teamwork perceptions were found to be statistically different between the science and engineering degrees. These results can impact the teaching methods in design education and the criteria for team assignments in subsequent iterations of this foundational event and other curricular materials centered on the engineering design process. The results of this study set a foundational element aimed at understanding the impact on first-year engineering students.

Keywords: Cornerstone design, first-year, engineering design, K-12 experience, Hackathon

1. Introduction

Cornerstone courses introduce students to the concept of design and aspects of real-world design challenges. Cornerstone courses also strive to increase the success of students at the undergraduate level, improving persistence through the degree. The students' desire, or motivation, to persist through the field of study is heavily dependent on their perception of their abilities and the alignment of their ability with the requirements for their degree. This is known as the student's self-efficacy, which has been shown as a critical factor and predictor of a student's success in engineering.

Examining the impact of the student's self-efficacy factors on first-year engineering students will help increase success in engineering design curriculum. As students start University, it has become more apparent that education has evolved in the last few years, primarily due to the COVID-19 pandemic [1]. To better understand these changes, educators need to evaluate incoming student profiles and track their success across their degree programs. Factors such as student demographics, self-efficacy, and prior experiences related to their degree field can produce an increased understanding of the impact of cornerstone courses. Each student enters the University with different backgrounds and experiences, and we want to evaluate if these different factors contribute to a student's success in engineering design education. These factors will be compared to the students' success in the cornerstone design course, and their success will be measured using the students' final grades in the course.

This study aims to address three research questions (RQ):

RQ1: How does prior STEM experience impact engineering design self-efficacy, and how does this impact student performance in a cornerstone design course?

RQ2: What self-efficacy factors are impacted by participation in a cornerstone design course and a student's approach to a design task?

RQ3: In what ways do students' academic majors correlate with self-efficacy factors and teamwork perception for students taking cornerstone?

2. Background

This study views the impact of cornerstone design on student engineering design self-efficacy through participation in a Hackathon style event. This section seeks to expand on the concepts of cornerstone, hackathons, the cornerstone course at the university, and the theoretical frameworks and survey instruments used for the study.

2.1 Cornerstone Design

Cornerstone design courses are a common feature of undergraduate engineering degrees [2], [3]. In a broad sense, cornerstone design courses are design projects aimed at freshman- and sophomore-level students. Cornerstone courses are comparable to senior-level capstone courses;

students must solve an engineering problem, typically with a team. Cornerstone design courses, in contrast to capstone design courses, provide students with more instruction to allow them to acclimate to undergraduate level study.

Universities have various ways of conducting cornerstones. For example, The Ohio State University's Fundamentals of Engineering [2] course assigns all first-year students to a ten-week project. Students are required to meet with faculty members and graduate teaching assistants offering academic and professional development opportunities for students. This open structure to the courses allows students to experience the iterative nature of design firsthand. Cornerstone courses also allow students to familiarize themselves with their peers and faculty members, creating a sense of belonging. The introduction to design and familiarity among peers and faculty has been shown to be vital for student success throughout their degree programs.

2.2 Hackathon Events

Hackathons originated in software development spaces meant to foster innovation. Typically, small groups of programmers would work together for a short period (one to three days) to develop a project [4]. This model has been adapted for the classroom setting. With this model, small groups of students are assigned a task and have a short period to complete said task. Key factors define the hackathon model: a primary purpose or task, pre-event preparations, pitch phase, mingling phase, development phase, presentations, and evaluation [5].

The hackathon model can be utilized for many different purposes in the classroom, one being a final project. Gama, *et al.* [6] utilized this model for undergraduate Computer Science and Information Technology students at a university in 2017. The goal of this event was for students "to develop a connected [Internet of Things] artifact tackling a real user problem." Students were divided into groups of three to four and given the same hardware to complete the project in a twenty-four hour time-limit. A survey was conducted after the event, and most students strongly agreed that they enjoyed the experience, and that the hackathon model could be used on other courses. Most students either somewhat agreed or strongly agreed that the event helped them generate ideas. Like cornerstone courses, the hackathon also allows students to familiarize themselves with their peers. Additionally, generating ideas is another vital skill for the engineering design field.

2.3 Cornerstone Design at The University

This study took place at a primarily undergraduate, STEM-focused institution with multiple cornerstone experiences for students, bridging a two-year sequence. The two first-year courses are required for all STEM majors at the University. The first course is designed for first-semester students and is offered in the fall. This course is designed to develop a student's academic and professional skills, delivered in an 8-week hybrid fashion, with only three in-person meetings with their instructor. The course culminates in a multidisciplinary hackathon-style project in which students have a total of six hours to complete their project. While the project evolves each semester, one example project requires the students to build, program, and test a robotic arm to complete a predefined set of tasks (for example, picking up a block and moving it back). Students are provided with basic instructions on completing the project and sample code, with faculty members present to aid students with issues that arise. Once complete, the students must complete a presentation detailing how long it took them, their challenges, and how they overcame them.

The students' second cornerstone course is an unofficial successor to the first course. In this course, students learn basic programming in Microsoft Excel, culminating in a hackathon which focuses on the analytical aspects of engineering. For this hackathon, students are given the same amount of instruction as the previous hackathon but must program an Arduino to control electromechanical components to operate an Etch-a-Sketch using Microsoft Excel. Students are provided with an Arduino, sample code, and sensors. Faculty members are also present to help students, and there is a closing presentation.

Subsequently, the University offers second-year 'cornerstone' bridge courses: one is required for all engineering students, and the other is engineering discipline-specific. The courses focus on professional development, graphical communication, technical writing, presentation skills, and the design process.

2.4 Engineering Design Self-Efficacy Survey

Self-efficacy describes students' beliefs that they can reach a goal or complete a task. While it is used synonymously with self-confidence, self-efficacy is more explicit [7]. Self-efficacy surveys are used to understand students' feelings about specific design tasks. As theory suggests, if students have high expectations of themselves, they are likelier to perform well [7], [8]. A study conducted at McMaster University [9] demonstrates this theory. This study surveyed one hundred eleven students presently or previously enrolled in their cornerstone course. Students were provided a survey of twenty-two questions divided into six categories: mastery experience, vicarious experiences, social persuasions, physiological states, drive and motion, and general self-efficacy questions. Students were additionally asked if they felt like engineers. This study showed that students who had completed the project felt more like engineers. Additionally, students who had already completed the project demonstrated increased self-efficacy and involvement over the students presently enrolled.

Another consideration affecting a student's self-efficacy is the belief that it is acceptable to take interpersonal risks [10]. In layman's terms, psychological (psych) safety is the shared belief that it is acceptable for team members to express their ideas and to speak up if they have questions or concerns. Psych safety is essential in cornerstone courses and hackathon style projects, as both rely on team building and trust. One study examined the relationship between psych safety and the "fluency and goodness of ideas" in a first-year cornerstone engineering design course [11]. It was determined that there was a statistically significant relationship between psych safety and “idea goodness”. If students felt that they could take more interpersonal risks, they were more likely to accept and be honest with each other. Teams need to communicate with each other; a relatively low-stakes environment – the classroom – is the perfect place to practice those skills. This was maintained in the hackathon event that was studied through granting students passing grades for attending and participating in the event, which accounted for a large portion of the class final grade.

3. Research Method

The study was conducted during the second-semester cornerstone design course taught at a primarily undergraduate, STEM-focused state university. As previously mentioned, this design course culminates in a hackathon and is commonly taught in a student's first year as an introductory course in analytical design. Students are exposed to new design concepts and are taught valuable skills to use throughout their design education journey. As this is only the students' second semester at the University, much of their knowledge base depends on their K-12 exposure to design principles. The authors seek to examine the students' background and prior experience and its impact on their self-efficacy toward design engineering.

For this study, students were given two surveys: one at the start of the course and one at the end. The surveys contained questions about demographics and engineering design self-efficacy (i.e. motivation, confidence, anxiety, and success) to evaluate how a student's background correlates within their engineering design education. These surveys are evaluated using statistical tests and regression analyses. This method of data collection, processing tools, and data storage were approved by the school’s Internal Review Board (IRB) prior to collection of the data.

3.1 Study Subjects

The study subjects included students in the spring hackathon design course. The demographics of the students correspond with the average size of classes at the University (n = 27). These demographics are shown below in Table 1. Due to the low number of survey participants, meaningful conclusions cannot be developed regarding certain demographics.

Table 1: Students' Demographics/Majors

	Mechanical Engineering	Electrical Engineering	Engineering Physics	Computer Engineering	Computer Science	Applied Mathematics	Total
Male	2	4	1	4	9	1	21
Female	2	0	0	0	0	1	3
Prefer not to say	0	0	0	1	2	0	3
Total	4	4	1	5	11	2	27

3.2 Data Collection

Quantitative data collection was achieved using surveys given to the students at two different times in the cornerstone design course. The first survey was conducted at the beginning of the spring semester before students started the course. This survey evaluated student demographics and self-efficacy. The students were then given the same self-efficacy survey at the end of the course after they completed their design projects. This allowed the authors to discuss any significant changes before and after a student took a cornerstone design course. Each factor is then compared to a student's overall performance within the cornerstone design course, which is measured using the student's final grades.

3.3 Analysis Method

The analysis performed to answer the proposed research questions is done using three statistical methods: t-tests, linear regression, and analysis of variance (ANOVA). These methods compare the study subjects and correlate them to relevant variables. Linear regression seeks to compare the dependent variable (student success) to the individual variables to identify the relationship between the two. The analysis was conducted using RStudio software to develop a linear regression model. T-tests are also conducted between student success and engineering design self-efficacy factors to consider the relationship between the two variables. Along with the t-tests, the authors performed ANOVA tests to compare the pre-survey data with the post-survey data. The values produced from the analysis are considered significant if $\alpha < 0.05$, however, values of $\alpha < 0.10$ are also discussed.

4. Results

The students answered several questions about design and were instructed to answer these questions based on the four self-efficacy factors: confidence, motivation, anxiety, and success. T-tests were used to measure the correlation of the four self-efficacy factors, examining the change over the course of the Hackathon. As expected, the students' confidence was of interest for their ability to conduct design and construct a prototype, where confidence was shown to increase, displayed in Table 2 and 3.

Table 2: Confidence in Conducting Engineering Design Paired T-Test Results

Evaluate/Test a Design	*Pre-*	*Post-*
Mean	37.56	52.26
Variance	733.56	979.89
Observations	27.00	27.00
t Stat	-3.29	
P(T<=t) two-tail	0.003	
t Critical two-tail	2.06	

Table 3: Confidence in Constructing a Prototype Paired T-Test Results

Construct a Prototype	*Pre-*	*Post-*
Mean	45.22	61.78
Variance	975.56	1102.56
Observations	27.00	27.00
t Stat	-3.31	
P(T<=t) two-tail	0.003	
t Critical two-tail	2.06	

Additionally, significant correlations were discovered for success. This correlation shows that students' perception of success increases when it comes to conducting engineering design, identifying and researching a design need, developing design solutions, constructing design prototypes, evaluating and testing design solutions, and conducting redesign. The t-test results are shown in the following (Table 4 - Table 10).

Table 4: Success in Conducting Engineering Design Paired T-Test Results

Conduct Engineering Design	*Pre-*	*Post-*
Mean	44.93	54.59
Variance	1057.38	1119.71
Observations	27.00	27.00
t Stat	-2.20	
P-value	0.04	
t Critical two-tail	2.06	

Table 5: Success in Identifying a Design Need Paired T-Test Results

Identify Design Needs	*Pre-*	*Post-*
Mean	47.63	58.19
Variance	1054.17	1033.54
Observations	27.00	27.00
t Stat	-2.83	
P-value	0.01	
t Critical two-tail	2.06	

Table 6: Success in Researching a Design Need Paired T-Test Results

Research Design Needs	*Pre-*	*Post-*
Mean	44.00	53.33
Variance	1111.00	1202.23
Observations	27.00	27.00
t Stat	-2.12	
P-value	0.04	
t Critical two-tail	2.06	

Table 7: Success in Developing a Design Solution Paired T-Test Results

Design Solution	*Pre-*	*Post-*
Mean	48.15	59.33
Variance	1049.52	1133.69
Observations	27.00	27.00
t Stat	-2.20	
P-value	0.04	
t Critical two-tail	2.06	

Table 8: Success in Constructing a Prototype Paired T-Test Results

Construct a Prototype	*Pre-*	*Post-*
Mean	44.00	53.33
Variance	1111.00	1202.23
Observations	27.00	27.00
t Stat	-2.12	
P-value	0.04	
t Critical two-tail	2.06	

Table 9: Success in Evaluating & Testing a Design Paired T-Test Results

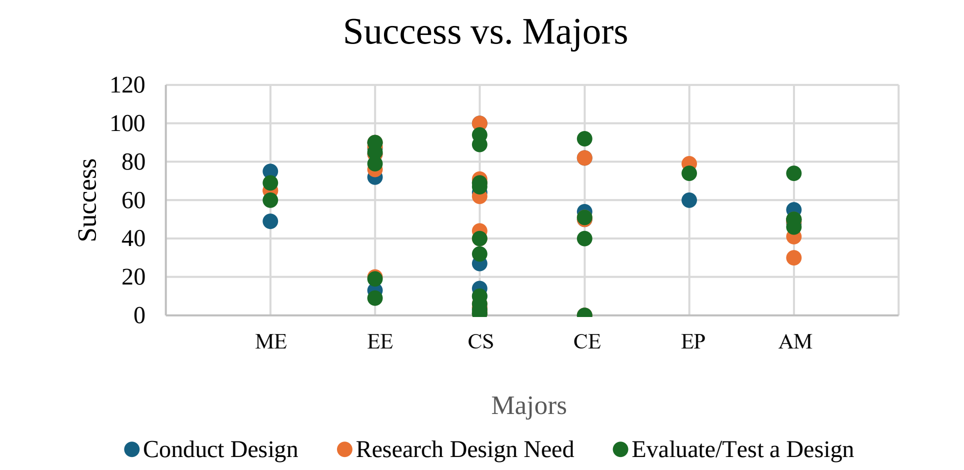
Evaluate/Test a Design	*Pre-*	*Post-*
Mean	48.15	59.33
Variance	1049.52	1133.69
Observations	27.00	27.00
t Stat	-2.2	
P-value	0.04	
t Critical two-tail	2.06	

Table 10: Success in Conducting Redesign Paired T-Test Results

Redesign	*Pre-*	*Post-*
Mean	42.89	55.81
Variance	1104.56	1138.31
Observations	27.00	27.00
t Stat	-3.46	
P-value	0.002	
t Critical two-tail	2.06	

The authors then wanted to see how the four self-efficacy factors related to student performance, majors, and prior experience. Due to the limited study subjects, the only significant correlation found through linear regression (Figure 1) was between majors and success. The results suggest that feeling successful in researching, conducting, and testing design solutions correlates with a student's major.

After conducting the linear regression, the authors looked further into what majors felt more successful before starting a design task. Looking at the averages between the majors, the major that felt the most successful with researching, conducting, and testing design solutions was determined to be computer engineering majors.



	Coefficient	*Std. Error*	*t Stat*	*P-value*
Intercept	12.50	0.42	30.10	< 2e-16
Success – Research Design Need	0.06	0.02	2.97	0.007
Success – Conduct Design	-0.03	0.02	-1.59	0.13
Success – Evaluate/Test a Design	-0.03	0.01	-2.01	0.06

Residual standard error: 1.13
F-statistic: 2.28
Model p-value: 0.04

Figure 1: Linear Regression - Success vs. Majors

Following the t-tests and linear regression, the authors performed ANOVA tests to determine if degree area (engineering vs. science majors) influenced self-efficacy factors and teamwork perceptions. The analysis found that the self-efficacy factors were not impacted by degree area, however degree area was shown to be influential in teamwork perceptions, specifically in positive perceptions. The analysis also revealed that negative perceptions of teamwork were nearly significant. This is reflected in Table 11 - Table 13 below.

Table 11: ANOVA Analysis – Overall Teamwork

Overall Teamwork Perception		**Results**
Engineering	**Mean**	2.252
	Variance	1.654
Science	**Mean**	1.824
	Variance	.917
P-Value	.007	

Table 12: ANOVA Analysis – Positive Teamwork

Positive Teamwork Perception		**Results**
Engineering	**Mean**	3.231
	Variance	1.104
Science	**Mean**	2.827
	Variance	1.03
P-Value	.0496	

Table 13: ANOVA Analysis – Negative Teamwork

Negative Teamwork Perception		**Results**
Engineering	**Mean**	0.949
	Variance	2.005
Science	**Mean**	.487
	Variance	.369
P-Value	.0668	

5. Discussion

The impact of engineering design confidence and success is present within the cornerstone design course at a STEM-focused state university. Also present within the course is the correlation between major and success with performing design tasks as well as teamwork perceptions. These results are significant with understanding the impact of self-efficacy on student performance in a cornerstone design course.

5.1 Self-Efficacy Factors: Confidence and Success

The cornerstone design students' self-efficacy factors of confidence and success were found to increase with the participation in the hackathon. More specifically, their *confidence* in conducting engineering design, and constructing a prototype; and their *success* in conducting engineering design, identifying and researching a design need, developing design solutions, constructing design prototypes, evaluating and testing design solutions, and conducting redesign. This addresses RQ2 and is an intriguing discovery as it suggests that students are confident in conducting design tasks and feel more likely to succeed following participation in cornerstone. Interestingly, while students' confidence and success increased, there was no correlation between these changes and students' final grades in the course. This finding highlights an important distinction: while confidence and success perceptions are critical for persistence and engagement, they do not always immediately translate into improved academic performance. This separation suggests that activities like hackathons are valuable not simply for boosting grades, but for building a student's belief in their own ability to navigate engineering challenges. This could imply longer-term effects on retention in STEM fields. Therefore, these correlations present the opportunity to enhance teaching methods within design education [12]. Teaching methodologies have been shown to correlate to students' self-efficacy, and adapting design education can improve student performance simply by improving students' motivation [13].

5.2 Self-Efficacy Factors vs. Majors

In addressing RQ3, the linear regression also revealed differences in how students from different majors experienced the hackathon. Students majoring in computer engineering reported feeling the most successful in conducting design tasks, suggesting that prior technical experiences or coursework may influence students' perceptions of their capabilities. This points to a possible advantage for students whose academic backgrounds are more closely aligned with the skills emphasized in the project. It also points to future research efforts in team composition and success. While different majors are assigned to each team to attempt to balance technical skillsets, this could be an input variable in future research.

Teamwork perceptions also varied by major. Engineering majors reported more positive teamwork experiences than science majors and generally held lower negative teamwork perceptions. This may reflect differences in how engineering programs emphasize collaborative project work compared to science curricula, particularly at the first-year level. To address this gap, instructors might consider implementing additional team-building activities or communication exercises early in the course, ensuring that students from all backgrounds are equally prepared to succeed in collaborative environments.

The authors believe that this insight is invaluable knowledge for future work. Being able to adapt teaching methods within design education to better enhance design teams can be impactful to students. Knowledge of the impact of majors can inform team formation to produce more confident and motivated students. Further, the correlation with teamwork perceptions could advise team formation, creating better team dynamics through both support and evaluation.

5.3 Limitations of the Study

The primary limitation for the study was the instances of data collection. Provided that the class is offered in a hybrid 8-week format, the data was also only collected at the beginning and end of the semester. This was done to prevent survey fatigue; however, it limited the data collected and resulted in limited student response to the post-survey. A further limiting factor of the study is the limited sample size. Many students submitted the survey, however, did not complete the full survey. This can be amended in the future with the survey being a required component towards the completion of the hackathon event.

6. Conclusion

This study examines the impact of student self-efficacy factors on student performance within cornerstone design. Data analysis included t-tests, ANOVA tests, and linear regression. The T-tests depicted correlation between confidence and success. It is important to consider that low confidence and success are normally associated with low grades, but this was not found to be significant in this case. This suggested that engineering design confidence, nor success, affect grades. The authors also determined a correlation between majors and success with linear regression. This correlation showed that computer engineering majors were prone to feeling more successful. This relationship is important to note as design education is heavily team-based. Knowing which majors feel successful can advise student design team formation. Ensuring that every cornerstone design team includes varying majors can influence the feeling of success in the team. Further this mixing of degrees could better establish team cohesion, improving overall experience. The correlation between self-efficacy factors, students' backgrounds, and the results allow for the opportunity to improve design education.

6.1 Future Work

The authors intend to expand the work conducted in this study by refining the surveys. While the surveys provided significant feedback for the authors to analyze, the surveys can be altered for better student completion. The authors also intend to improve this study by evaluating how these factors change over time within multiple design courses to see if factors such as prior experience and demographics affect student design education. The authors seek to create predictive models using artificial intelligence and machine learning to predict student performance based on several factors evaluated in this study. Analyzing student data in different stages of the design course sequence at the University will allow the authors to obtain more effective feedback to create these predictive models.

Another area of potential interest is the incorporation of artificial intelligence that can be utilized in design education practice. Figure 2 shows how artificial intelligence can help us see and predict the relationship between teaching methods and student self-efficacy, leading to improved design course outcomes. Being able to understand these relationships is crucial to improving design education, through increasing student interest and participation.

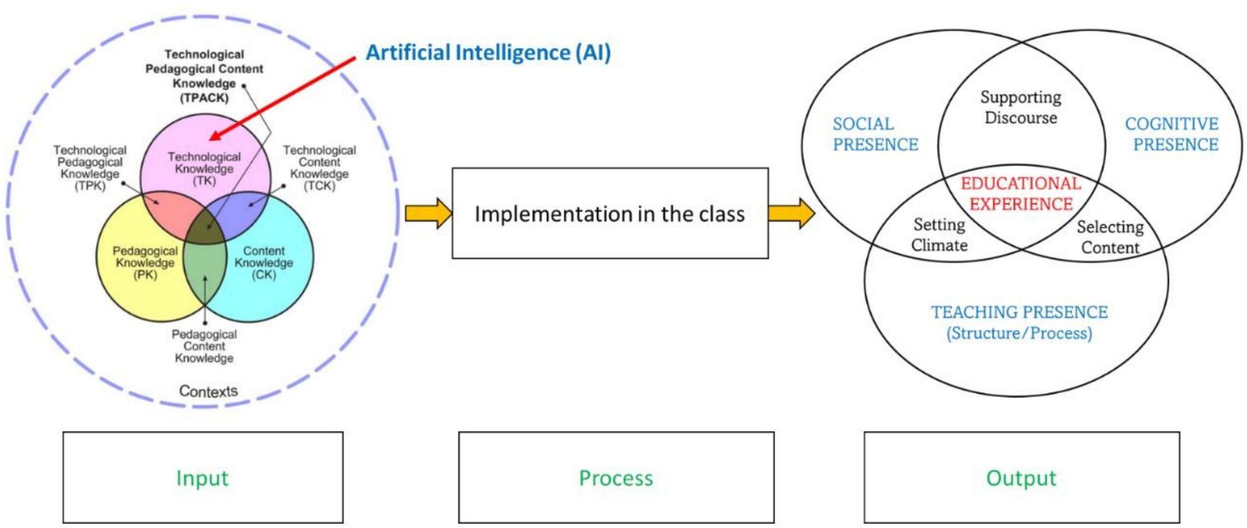


Figure 2: Knowledge Requirement for Engineering Educators Diagram for Incorporating Artificial Intelligence

Alongside using artificial intelligence to create predictive models, the authors intend to evaluate these models via neurocognitive examination of students [14]. This will allow the authors to predict students' self-efficacy factors before approaching a design task and during the completion of a design task, comparing it to how the students felt about the design task. From these further investigations, it is the goal of the authors to develop a robust cornerstone pedagogy. This will meet the requirements of the university serving as an introductory course in engineering and design but will also seek to effectively develop the skills required in design and the student's interpersonal factors, such as self-efficacy.

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