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WIP: Exploring Connections Between Self-Efficacy, Engagement, and Perceived Importance in First-Year Engineering Design

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Introduction

Assessing student learning in design-based engineering courses requires attention to both technical competencies and affective dimensions such as confidence, motivation, and perceived value. First-year engineering design experiences, in particular, aim not only to develop foundational technical and design skills but also to support students' emerging identities as engineers, their willingness to engage with open-ended problems, and their perceptions of the relevance of engineering to societal needs. Prior work in engineering education has shown that affective factors such as self-efficacy and engagement play a critical role in how students approach design tasks, persist through uncertainty, and make sense of their learning experiences [1]-[7]. As a result, assessments that focus exclusively on technical outcomes risk overlooking key dimensions of learning that influence how students participate in and benefit from design-based instruction.

Many existing assessment approaches in engineering design education examine these constructs in isolation, providing limited insight into how affective and cognitive dimensions interact to shape students' learning experiences. Instruments often focus on a single outcome—such as self-efficacy, engagement, or attitudes toward engineering—without examining how these factors may co-evolve across different learning domains within a course [3],[4],[8]-[10]. Self-efficacy, grounded in social cognitive theory (e.g., [1]), has been widely studied in relation to students' confidence in performing engineering tasks, while engagement has been examined as a multidimensional construct. Perceived importance or value has been linked to motivation and sustained participation in engineering. The fragmentation, however, makes it difficult to understand, for example, how students' confidence in design relates to their engagement in teamwork or their perceived importance of social responsibility in engineering practice. Without assessment tools that explicitly capture relationships among constructs, instructors and researchers lack the means to explore and support holistic student development.

The purpose of this work is to develop and pilot an assessment instrument designed to examine the relationships among self-efficacy, engagement, and perceived importance within a first-year engineering design course. This study adopts an integrated perspective that considers how affective and cognitive dimensions align with core course competencies, including engineering design, teamwork and communication, technical skills, and social responsibility. The research focuses on the initial implementation and evaluation of the instrument, with particular attention to internal consistency, coherence across domains, and alignment between specific behavioral indicators and general measures of engagement and confidence. By emphasizing relationships among constructs rather than isolated measures, this work aims to provide a foundation for more holistic assessment of learning in design-based engineering education.

Conceptual Framework/Theoretical Grounding

This work is grounded in a conceptual framework that integrates affective and cognitive dimensions of learning within the context of first-year engineering design. Design-based engineering courses are inherently complex learning environments, requiring students to engage with open-ended problems, collaborate with peers, apply technical knowledge, and reflect on the broader impacts of engineering. As a result, students' learning experiences are shaped not only by what they are able to do, but also by how confident they feel in their abilities, how engaged they are in course activities, and how much value they attribute to different aspects of the course.

Self-Efficacy: Self-efficacy refers to individuals' beliefs in their capability to perform specific tasks or succeed in particular situations and is a well-established predictor of motivation, persistence, and performance. Drawing on social cognitive theory (e.g., [1]), self-efficacy is understood as task- and context-specific rather than a generalized trait. In engineering education, self-efficacy has been linked to students' willingness to engage with challenging problems, persist through failure, and develop confidence in applying engineering practices. Within design-based courses, self-efficacy is particularly salient, as students are frequently asked to navigate uncertainty, iterate on solutions, and make design decisions with limited prior experience [3],[8],[11]-[13]. Accordingly, this study conceptualizes self-efficacy as students' perceived confidence in engaging with key course competencies rather than as a single, course-wide measure.

Engagement: Engagement is a multidimensional construct encompassing behavioral, emotional, and cognitive components [14]. In the context of engineering design education, engagement manifests through students' active participation in design activities, collaboration with teammates, initiative in problem solving, and reflection on their learning processes. Prior work has shown that engagement is closely related to both affective factors, such as interest and confidence, and instructional features, such as project structure and team dynamics [9],[15]. In this study, engagement is conceptualized as both a general orientation toward the course and a set of observable behaviors aligned with design-based learning. By including both broad indicators of engagement and more specific behavioral items, the framework acknowledges that students' overall sense of engagement emerges from their experiences across multiple activities and interactions within the course.

Perceived Importance (Value): Perceived importance, often discussed in relation to task value and expectancy-value theories of motivation, reflects the extent to which students view learning activities or outcomes as meaningful, useful, or relevant [16]-[18]. In first-year engineering design courses, perceived importance may be shaped by students' views of engineering as a discipline, their understanding of professional engineering practice, and their beliefs about the societal role of engineers [15],[19]. Prior research suggests that when students perceive course content as valuable, they are more likely to engage deeply and persist through challenges [16] [16]. In this work, perceived importance is framed as students' valuation of the core competencies emphasized in the course, recognizing that students may attribute different levels of importance to technical skills, teamwork, design practices, and social responsibility.

Integrated Conceptual Framework: Rather than treating self-efficacy, engagement, and perceived importance as independent outcomes, this study adopts an integrated conceptual framework in which these constructs are expected to be interrelated and mutually reinforcing. For example, students who perceive competency as important may be more motivated to engage in related activities, which in turn may support the development of self-efficacy through successful experiences. Conversely, low confidence or limited engagement may influence how students value certain aspects of the course. This framework informed the design of the assessment instrument, which aligns all three constructs with four core course competencies: engineering design, teamwork and communication, technical skills, and social responsibility. By situating affective constructs within specific learning domains, the framework enables examination of how students' confidence, engagement, and perceived importance co-evolve within and across competencies in a first-year engineering design context.

Methods

Course Context: This study was conducted in a required first-year engineering design course within the College of Engineering at Villanova University. The course introduces students to engineering design through team-based, project-driven experiences that emphasize problem

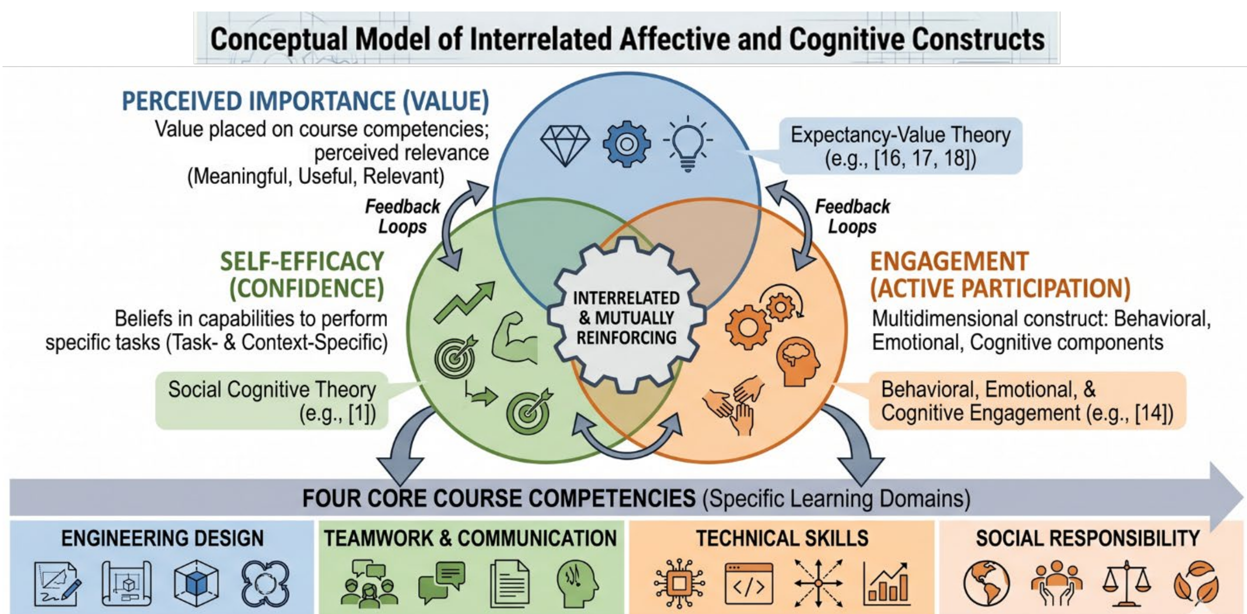

Figure 1. Integrated conceptual framework guiding this study. In the first-year engineering design context, self-efficacy, engagement, and perceived importance are interrelated and mutually reinforcing. These constructs are examined across four core competencies: engineering design, teamwork and communication, technical skills, and social responsibility.

scoping, iterative design, prototyping, communication, and reflection. In addition to technical and design skills, the course explicitly foregrounds teamwork, communication, and social responsibility as core learning outcomes. Instructional activities include collaborative design projects, structured reflection assignments, in-class discussions, and hands-on prototyping, providing multiple opportunities for students to engage cognitively, behaviorally, and affectively with course content. The assessment instrument described in this study was embedded into the course and aligned with the course's four core competencies: engineering design, teamwork and communication, technical skills, and social responsibility.

Sample: Participants included first-year engineering students enrolled in the course during the Fall 2024 semester (6 sections, 6 instructors). Participation in the study was voluntary, and responses were anonymized prior to analysis. Institutional review board (IRB) approval was obtained prior to data collection.

Instrument Design: We examined relationships among the three constructs situated within the context of the course's four core competencies. For each competency, students responded to parallel sets of items measuring self-efficacy (confidence in performing related tasks) and perceived importance (how important student felt the learning outcomes were for their formation as an engineer). These items were administered both at the beginning (pre-course) and end (post-course) of the semester to capture changes over time.

Engagement was measured through a post-course survey that included both general items (e.g., overall engagement in the course) and specific behavioral items aligned with design-based learning practices, such as initiative, collaboration, and reflection. This structure was intentionally designed to allow analysis of how specific behaviors relate to broader perceptions of engagement and confidence.

All items used 5-point Likert-type response scales. Instrument development was informed by prior research on affective constructs in engineering education and iteratively refined through instructor feedback and pilot testing.

Data Collection: Survey data were collected electronically during regular course administration at designated time points. Pre-course surveys were administered during the first week of the semester, while post-course surveys were administered during the final weeks of the course. Open-ended response items were included in the post-course survey to provide qualitative context for interpreting quantitative results and to support instrument refinement.

Data Analysis: Analysis focused on evaluating the internal consistency and coherence of the assessment instrument during its initial implementation. Reliability was examined using Cronbach's alpha for each construct across the full instrument as well as within each of the four competency domains. Item-total correlations were calculated to assess how individual items contributed to their respective scales. Correlation analyses were conducted to examine alignment between specific behavioral engagement items and general indicators of engagement and self-efficacy. Where weaker relationships were identified, qualitative responses and instructor reflections were used to contextualize findings and guide item revision. Given the exploratory nature of this initial implementation, analyses focused on descriptive and correlational statistics rather than causal inference. Open ended questions were analyzed using thematic analysis.

Preliminary Results

Preliminary analyses are based on survey (150 items) data collected during the Fall 2024 implementation of the assessment instrument. Of the 155 students (54% of students enrolled) who accessed the post-course survey, 125 provided partial or complete responses suitable for analysis. Completion rates varied across survey sections, with the engagement section fully completed by all 125 students, while matched pre–post responses for perceived importance were available for 52 students. Given the exploratory and validation-focused nature of this work, analyses were conducted at the section level where sufficient data were available. Descriptive, reliability, and correlational analyses are reported to examine internal consistency, coherence across items, and alignment between constructs.

Reliability of Assessment Constructs

All sections demonstrated excellent reliability, with α values ranging from 0.92 to 0.98 (Table 1). Engagement items yielded a Cronbach's α of 0.92, while self-efficacy and perceived importance scales demonstrated α values above 0.95 across both pre- and post-course administrations. Reliability was also examined within each of the four course competency domains with consistently high values across domains. These results indicate that the instrument reliably measures its intended constructs and supports the use of composite scores for subsequent analyses. The high α values also suggest potential redundancy among some items, particularly within the engagement scale, informing future item refinement.

Table 1. Cronbach's alpha values for engagement, self-efficacy, and perceived importance

Section	Cronbach's Alpha
Engagement (1–11)	0.92
PreConfidence (1–30)	0.97
PostConfidence (1–30)	0.98
PreImportance (1–30)	0.98
PostImportance (1–30)	0.98

Student Engagement Patterns

Descriptive statistics for engagement items indicated a generally high level of student engagement in the course. Across the eleven engagement items, mean scores ranged from approximately 3.5 to 4.4 on a five-point Likert scale, with medians clustering around 4 ("Somewhat agree"). The highest-rated item was students' sense of accomplishment when completing course tasks, while the lowest-rated items related to independent reflection and exploration beyond course requirements. To examine coherence within the engagement construct, correlations were calculated between a general engagement item ("I feel engaged in the course") and each specific engagement behavior. As summarized in Table 2, both Pearson and Spearman correlations revealed consistent patterns. Stronger correlations were observed for items related to enjoyment, challenge, effort, and accomplishment ($r \approx 0.6–0.7$), while the weakest correlation was observed for initiative beyond course requirements ($r \approx 0.2$). Item-total correlations, shown in Table 3, further confirmed that all engagement items contributed meaningfully to the overall scale, with values exceeding common thresholds for acceptable contribution.

Table 2. Correlations between general engagement and specific engagement behaviors.

Question	Pearson Correlation	Spearman Correlation
I consistently prepare for class	0.6	0.5
I put a great deal of effort into advancing my learning in the course	0.6	0.5
I am challenged to learn more than I expected in this course	0.7	0.6
I enjoy my time in this class	0.7	0.6
I actively participate in class activities and discussions	0.5	0.4
I seek help from my instructor or peers when I have difficulty understanding the material	0.5	0.4
I regularly review and reflect on the course content outside of class	0.5	0.5
I take initiative to explore topics beyond the course requirements	0.2	0.2
I find myself thinking about the course topics even outside of class time	0.5	0.4
I feel a sense of accomplishment when I complete tasks and activities in class	0.6	0.5

Table 3. Item total correlations between general engagement and specific engagement behaviors.

Question	Item-Total Corr (with Engagement)	Item-Total Corr (without Engagement)
I feel engaged in the course	0.7	
I consistently prepare for class	0.8	0.8
I put a great deal of effort into advancing my learning in the course	0.8	0.8
I am challenged to learn more than I expected in this course	0.7	0.7
I enjoy my time in this class	0.7	0.7
I actively participate in class activities and discussions	0.7	0.7
I seek help from my instructor or peers when I have difficulty understanding the material	0.6	0.6
I regularly review and reflect on the course content outside of class	0.7	0.7
I take initiative to explore topics beyond the course requirements	0.5	0.5
I find myself thinking about the course topics even outside of class time	0.6	0.6
I feel a sense of accomplishment when I complete tasks and activities in class	0.8	0.8

Together, these results suggest that engagement in the course was primarily driven by structured, in-class activities and a sense of challenge and accomplishment, while engagement outside of required activities was less prominent.

Qualitative Engagement Findings

Open-ended engagement questions were analyzed using inductive thematic coding to provide context for the quantitative findings. For the question asking which aspects of the course most contributed to engagement and learning, the most frequently identified themes were hands-on activities and projects, followed by group work and collaboration. Students frequently referenced activities such as prototyping, design projects, and technical skill development (e.g., CAD and programming) as particularly impactful. In contrast, responses describing challenges to engagement most commonly cited time constraints and group dynamics, though a substantial number of students explicitly reported no significant challenges. Lecture format and clarity were also noted as areas for improvement by a subset of respondents.

These qualitative findings reinforce the central role of experiential, collaborative learning in driving engagement, while also highlighting areas such as independent exploration and course structure—that may warrant additional instructional support.

Table 4. Themes and representative quotes from qualitative engagement responses.

Themes for : "What aspects of the course contributed to your engagement and learning? Please describe any specific activities, discussions, or experiences that you found particularly impactful."			
Theme	**Description**	**Example Quote**	**Number of mentions**
Hands-on activities/projects	Physical, practical tasks (e.g., Arduino, CAD, design briefs, building models).	"I loved the physical hands-on aspect of this course, especially the Arduino project."	43
Group work/collaboration	Team projects, peer interaction, working with others.	"Working in teams helped me stay engaged and learn how to collaborate effectively."	35
Learning new skills	Gaining technical or design skills; new concepts.	"The course taught me CAD and coding, which I had never done before."	24
Creative/fun aspect	Elements described as enjoyable, interesting, or innovative.	"The design briefs were fun and allowed me to be creative."	16
Instructor/course quality	Praise for course design, clarity, or instructor's role.	"Great professor and a well-organized curriculum kept me interested."	2
Themes for: “Were there any challenges or obstacles that made it difficult for you to engage fully in the course? If so, how did you address them, and what could have been done differently to enhance your experience?"			
Theme	**Description**	**Example Quote**	**Number of mentions**
No improvements (positive feedback)	Students said nothing needed improvement / no challenges reported.	"No issues at all—it was a great experience overall."	32
Time constraints/personal challenges	Issues like workload, time management, external life challenges.	"Balancing the workload with other classes was difficult at times."	21

Group issues	Problems with group dynamics, participation, or communication.	"Some group members didn't contribute equally, which was frustrating."	16
Lectures (too long/boring)	Complaints about lecture format, length, or engagement level.	"The lectures sometimes felt long and hard to focus on."	8
Lack of background knowledge/confusion	Struggles with understanding course content or unclear instructions.	"I sometimes didn't feel prepared enough for the technical parts."	2

Changes in Perceived Importance of Learning Outcomes

Matched pre–post responses for perceived importance were available for 52 students. Reliability analyses demonstrated high internal consistency across all four competency domains at both time points (α = 0.94–0.97). Given this consistency, analyses focused on domain-level composite scores rather than individual items. Statistically significant increases in perceived importance were observed for all four competencies (Table 5). Mean post-course scores increased to approximately 4.2–4.5 across domains. These results indicate that students placed greater value on all core learning outcomes by the end of the course.

Table 5. Pre–post changes in perceived importance across course competencies.

Competencies	**Pre**					**Post**				
	Min	**Max**	**Median**	**Mean**	**Standard Deviation**	**Min**	**Max**	**Median**	**Mean**	**Standard Deviation**
Social Responsibility	1.4	5	3.4	3.5	0.9	2.9	5	4.4	4.4	0.6
Engineering Design	1.7	5	3.7	3.6	0.9	2.9	5	4.6	4.4	0.6
Teamwork and Communication	1.9	5	4.0	3.8	0.9	3.0	5	4.8	4.5	0.6
Technical Skills	1.0	5	3.5	3.5	1.0	1.7	5	4.0	4.2	1.7

Conclusion, Limitations and Next Steps

This work-in-progress paper represents an initial stage in the development of an assessment instrument examining relationships among affective constructs in first-year engineering design. The analyses focus on internal consistency and variable-level associations; however, correlation analyses do not account for measurement error or fully capture relationships at the latent construct level. Future work will incorporate confirmatory factor analysis and structural equation modeling to more rigorously evaluate both the measurement model and relationships among self-efficacy, engagement, and perceived importance. This study also does not include performance-based outcomes such as project or course grades. While informative, such measures can be difficult to interpret in design-based courses due to their team-based and multi-component nature. Future work will explore how affective constructs relate to student performance. Finally, data were collected from a single first-year course at one institution. Future studies will expand to multiple institutions and explore the use of the instrument beyond the first year to examine how these constructs develop across the engineering curriculum.

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