Enhancing engineering students' growth mindset through design thinking

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Abstract: This study investigated the impact of integrating design thinking into an engineering course on engineering students' growth mindset. Growth mindset is defined as the belief that intelligence can be developed through effort rather than being static. Growth mindset is critical for overcoming challenges in engineering education, yet traditional pedagogies often overlook cultivating engineering students' growth mindset. Using a mixed methods design, this research explored whether design thinking, with its iteration of empathy, definition, ideation, prototyping and evaluation, fostered engineering students' growth mindset. Preliminary findings suggested improvements in students' growth mindset. The findings presented significant implications for curriculum design and promote mindset-oriented pedagogies in STEM education.

Introduction

College engineering education programs in college continues to face persistent challenges, including high attrition rates (Callahan et al., 2022; Litzler & Young, 2012), student anxiety (Yanik et al., 2016), and a lack of student self-efficacy (Matta et al., 2023). Research has suggested those challenges are often linked to students' fixed mindset beliefs, in which students perceive intelligence as a static trait (Campbell et al., 2021). This fixed mindset belief tends to discourage perseverance, leading students to disengage when faced with academic difficulties in engineering courses (Henry et al., 2019).

To maintain student perseverance and improve their resilience, cultivating their growth mindset serves as an alternative (Reid & Ferguson, 2014; Zerin & Ratanalert, 2024). Growth mindset, in contrast to a fixed mindset, is defined as the belief that intelligence are not innate, unchangeable traits but can be malleable through deliberate practices (Dweck, 2006, 2013). Students with a growth mindset tend to view challenges as opportunities to learn and develop their abilities, which has been shown to enhance their academic achievement (Yeager et al., 2019; Yeager & Dweck, 2020).

One promising approach to develop engineering students' growth mindset is design thinking (Dadswell et al., 2024; Yeager et al., 2016; Yeh et al., 2024). Design thinking is a human-centered approach in which students approach design challenges with an emphasis on understanding the user's needs and developing solutions that prioritize those needs (Gumina & Tang, 2021; Li et al., 2019). Integrating design thinking into engineering curricula encourages students to embrace challenges and experiment with solutions, as this approach provides structured opportunities for students to collaboratively go through iteration, refinement, and feedback (Claro et al., 2016; Dadswell et al., 2024). To this end, design thinking reinforces students' belief that intelligence can be developed through elaborate and persistent practices, ultimately cultivating a growth mindset (Reid & Ferguson, 2014; Yeh et al., 2024).

Therefore, this study aimed to integrate design thinking into an undergraduate engineering course and examined its impact on developing engineering students' mindset beliefs. The findings of this study provided actionable insights for engineering educators seeking to enhance student engagement and build their growth mindset in college engineering programs.

Literature Review

Growth Mindset in Engineering Education

Growth mindset, defined as the belief that intellectual abilities are malleable through effort and practice, has been linked to improved resilience and academic persistence in STEM fields (Dweck, 2006, 2013). In engineering education, students with growth mindsets are more likely to persevere through complicated challenges (Campbell et al., 2021). Particularly, growth mindsets empower students to reframe setbacks as opportunities for learning and experimenting with adaptive learning strategies to resolve setbacks (Beyer, 2014; Claro et al., 2016). However, traditional engineering curricula often inadvertently reinforce students' fixed mindsets by determining mastery as a binary of pass or failure (Campbell et al., 2021; Frary, 2018). For instance, traditional programming courses primarily prioritizes outcomes over process by emphasizing error-free code execution, which focuses on writing flawless code; however, a pilot study occurred in a SAS programming seminar found that most students preferred the error-full method, which intentionally engaged students in learning by debugging erroneous codes (Hoffman & and Elmi, 2021). This misalignment between engineering curricular and growth mindset calls for effort to reframe engineering education by considering errors and failures as a critical part of students' knowledge growth and skill mastery (Yeager et al., 2019).

Design Thinking

Design thinking offers a human-centered framework that includes an iterative cycle of empathy, definition, ideation, prototyping, and evaluation (Jiang et al., 2023; Li et al., 2019). In engineering education, design thinking has been shown to enhance creativity by encouraging students to view challenges as opportunities for experimenting with innovative solutions (Guaman-Quintanilla et al., 2023; Gumina & Tang, 2021), making it a promising approach for developing students' growth mindset. Preliminary work has also linked design thinking to students' awareness of multiple perspectives of problems and their solutions, which is a key component of growth mindset. Particularly, Henriksen et al. (2017) noted definition and ideation played a crucial role in enabling students to view problems from multiple perspectives and generate innovative ideas. Guaman-Quintanilla et al. (2023) followed a "Double Diamond" model to structure design thinking in a freshman engineering course, with research, empathy, and definition in the first phase and ideation, prototyping, and validation in the second. Based on their findings, Guaman-Quintanilla et al. (2023) speculated that the ideation, prototyping, and validation phase had a larger impact on their divergent thinking. Despite these promising results, relatively few studies have explicitly examined how design thinking pedagogy directly influences the development of engineering students' growth mindset in college engineering courses. This study thus tapped into the direct connection between engineering students' experience with design thinking and their growth mindset beliefs.

Methodology

Participants and Setting

For this study, a mixed methods design (Creswell & Clark, 2017; Tang et al., 2020, 2021) was employed to comprehensively investigate engineering students' growth mindset shifts in a design thinking intervention. Undergraduate engineering students ($N = 43$) enrolled in two sections of a 15-week course at a public university participated in this study. The course sections were taught by the same instructor, and there were no preexisting differences in GPA or pre-test growth mindset scores between participants. Students were randomly assigned to an experimental group or a control group. The control group received traditional instruction, which included lectures and classroom discussions. In contrast, the experimental group engaged participants in a design thinking intervention centered on an authentic project.

The design thinking framework guided students through five iterative stages: empathy, definition, ideation, prototyping, and evaluation. Participants began with a field visit, where they interacted with staff to build empathy and identify specific needs. Working in groups, they then defined problems and brainstormed potential solutions. During the prototyping phase, participants developed prototypes, which they presented to an expert panel for testing and feedback. In the end, participants submitted their design brief and revised prototypes as the final product in groups.

Data Collection

Quantitative data were collected through pre- and post-surveys adapted from Dweck's (2006) Mindset Scale to measure changes in their mindsets and beliefs about intelligence and ability. To complement the quantitative data, qualitative data were gathered through design briefs and semi-structured focus group interviews with purposively selected participants to inquire about participants' perception of their learning experience and mindset shifts in this course.

Data Analysis

For quantitative data, descriptive statistics including mean (M) and standard deviation (SD) were provided. ANCOVA was then used to compare the difference in their growth mindset between the experimental group and the control group, using the pre-test growth mindset scores as a covariate. Partial eta squared was calculated to determine the effect size, with values below .01 indicating a small effect, while .06 and .14 served as threshold values for medium and large effect sizes, respectively. (Cohen, 1960). Qualitative data were analyzed using inductive analysis (Saldaña, 2021) to identify codes, patterns and themes in participants' description of their own learning experience.

Results

The ANOVA results showed statistically significant differences in participants' growth mindset between the experimental group ($M = 3.32$, $SD = 0.24$) and the control group ($M = 3.27$, $SD = 0.29$) after attending the design thinking activities, $F = 9.65$, $p = .003$, $\eta^2 = 0.19$, with a large effect size. Inductive analysis of qualitative data identified three preliminary themes such as "increased awareness of contexts", "enhanced learner engagement", and "promoted a mindset shift toward embracing challenges".

Discussion

Preliminary findings indicated that design thinking provided students with a systemic approach to developing their growth mindset, which has been linked to persistence and resilience in engineering education (Campbell et al., 2021; Yeager et al., 2016). However, limitations include potential data bias from self-report data and the constraints of small sample size from the same institution. Future research may explore longitudinal impacts in a cross-institution large sample of engineering students. Additional future work may consider collecting multimodal data to illustrate learning process and identify nuanced findings on the interaction between engineering students' mindset shift and their engagement in design thinking activities.

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