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”I felt like an engineer”: Exploring the impact of 3D printing sessions on rural high school students’ engineering self-efficacy

Hengtao Tang, University of South Carolina

Hengtao Tang is an associate professor in Learning, Design and Technologies at the University of South Carolina. His research focuses on self-regulated learning in engineering education, especially using learning analytics and machine learning algorithms to understand the self-regulated learning process, profile self-regulated learners, and create AI-scaffolded interventions to support self-regulated learning.

Dr. Yingxiao Qian, University of South Carolina

Dr. Yingxiao Qian is a clinical assistant professor in Learning Design and Technologies at the University of South Carolina. Her research interest is to design and develop various learning environments that utilize technology to enhance K-12 students’ real-world problem-solving abilities in STEM education contexts.

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Abstract

This study explored the impact of a 3D printing program on rural high school students’ engineering self-efficacy. Engineering self-efficacy, defined as one’s belief in their ability to succeed in engineering tasks, is a crucial predictor of whether students remain engaged in engineering education or pursue engineering as a college major. This is especially critical in rural settings, where access to engineering education or career development opportunities may be limited. To address this, the mixed methods study implemented a 3D printing experience centered on engaging students in hands-on making and tinkering activities. The quantitative component employed a design one-group pre- and post-test design using a modified version of Mamaril et al.’s (2016) engineering self-efficacy survey to assess students’ self-efficacy levels before and after their participation in the 3D printing activities. The qualitative inquiry focused on students’ perception of their engineering self-efficacy and their experience with the making activities. Quantitative results demonstrated a significant increase in students’ engineering self-efficacy following the 3D printing experience. Qualitative findings supported these quantitative results, indicating that the hands-on making and tinkering activities, especially when tied to real-world contexts, helped rural students build confidence, persistence, and problem solving skills in engineering. Together, these findings highlighted the potential of integrating 3D printing into rural education as a powerful tool to foster students’ self-perception as capable engineers and to promote broader access to STEM learning opportunities.

Introduction

Rural communities have long faced the challenge of skilled workforce leaving for urban areas in search of better career opportunities, which undermines their development and innovation as well as widens the rural-urban divide (Sano et al., 2020). Promoting pathways into engineering careers offers a promising strategy to mitigate this issue, especially given rural areas have seen the rising investment in engineering industries and increasing opportunities of well-paid engineering careers. Allowing rural students to participate in engineering career pathways can thus foster a locally rooted workforce and, in turn, strengthen the economic resilience of rural communities (Tang et al., 2024).

Cultivating rural students’ readiness for engineering careers is thus critical, but one of the challenges is to develop their self-efficacy towards engineering. Rural students are disadvantaged in accessing engineering education due to shortages of qualified educators, infrastructure, and funding (Tang & Qian, 2025). In addition, rural students have substantial proficiency gaps in relevant domains such as mathematics and science, which also adversely affect their confidence in purposing an engineering career.

Self-efficacy is defined as one’s confidence in their competence of accomplishing a particular task (Bandura, 1977). Research has shown that self-efficacy can be fostered in multiple ways such as mastery experience, vicarious experience, social persuasion, and physiological and affective states (Lee & Bong, 2023). Particularly, 3D printing has the potential to foster student self-efficacy through its tangible, creative STEM experiences (Buechley & Ta, 2023; Saorín et al., 2017). 3D printing allows students to visualize and physically create engineering solutions and provide an immediate connection between abstract concepts and real-world applications.

This study thus explored the impact of a 3D printing experience on rural students' self-efficacy towards engineering. Specifically, it seeks to answer the following research question: To what extent and in what ways does 3D printing experience impact rural students' engineering self-efficacy?

Methodology

A convergent mixed method design was used in this study (Creswell & Clark, 2017). Particularly, the quantitative components applied self-reported surveys to determine if statistically significant changes existed in rural students' perceived engineering self-efficacy before and after the 3D printing experience. The qualitative inquiry focused on rural students' descriptions of their learning experience and their perception of engineering self-efficacy. The findings from the two sources of data were synthesized to answer the research question.

Participants and Contexts

The study occurred at a rural public high school in the southeastern United States. An intervention exposing gifted students to making and tinkering practices was integrated into leadership breakout group sessions. This breakout group met once every week for 45 minutes. An Institutional Review Board (IRB) approval was granted before recruiting participants. A total of 11 enrolled students returned the consent and assent form, confirming that they would voluntarily participate in the study. The sample of participants included six female and five male students with an average age of 17 years old.

3D Printing Program

Participants participated in a series of hands-on learning activities in which they were tasked with designing and prototyping a tool for the future using 3D printing. A teacher facilitator served to teach participants how to use 3D printers and 3D modelling software and offer ongoing guidance on resolving any issues related to 3D models and printing. They began by developing digital 3D models using AutoCAD and Tinkercad and subsequently prototyped their design using 3D printing. Participants also had the opportunity of iteratively revising their models and resubmitting their design to the 3D printers if their prior solution did not work. The teacher facilitator would also provide technical support to ensure participants could continue with the design process.

Data Collection and Analysis

For the quantitative data collection, Mamaril et al.'s (2016) engineering self-efficacy survey was adapted to assess the participants' perceived engineering self-efficacy. Descriptive statistics were provided. Dependent sample t-test was performed to investigate the change in participants' engineering self-efficacy before and after attending the 3D printing sessions.

For the qualitative data collection, purposively selected participants were invited to complete semi-structured interviews with the research team. A semi-structured protocol was developed with a focus on participants' perception of 3D printing and its impact on their self-efficacy in engineering (Gikas & Grant, 2013). Each interview was conducted individually in the classroom of the 3D printing session upon the completion of the study. The interview lasted between 25 and 40 minutes. For data analysis, each interview was recorded and transcribed with permissions from the participants. Inductive analysis (Creswell & Creswell, 2017), including two cycles of coding (Saldaña, 2021), was conducted to elicit themes.

Results

Quantitative Findings

A dependent samples *t*-test was conducted to evaluate changes in participants' engineering self-efficacy before and after the 3D printing program (n = 11). Results indicated a statistically significant increase in self-efficacy scores from pre-test (M = 3.21, SD = 0.49) to post-test (M = 3.89, SD = 0.38), $t(10) = 4.73$, $p < .001$, with a large effect size (Cohen's d = 1.42). These findings suggest that participation in the 3D printing sessions positively influenced students' confidence in their engineering-related abilities, such as problem-solving, design iteration, and technical skills.

Qualitative Findings

Inductive analysis of participants' responses to interview questions provided deeper insights into how the 3D printing experience influenced their self-efficacy in the engineering domain. Three themes emerged from the qualitative data.

Theme 1: Hands-on learning increased engagement

Students overwhelmingly reported that the hands-on nature of 3D printing made engineering concepts more engaging and understandable. Many described the experience as "exciting" and "fun," emphasizing that physically designing and printing objects helped them see how engineering applies to real-world problems.

> *"I never thought I would enjoy engineering, but 3D printing made it more interesting. Seeing my design come to life was really cool."*

> *"Usually, I find science and math boring, but when I got to create my own design and see it printed, I felt like an engineer."*

Theme 2: 3D printing experience improved student confidence in problem solving

Many students expressed an increased confidence in their ability to solve authentic problems and refine their ideas through iterative design. They also emphasized how learning through iterative processes helped them persist despite challenges.

“When my first design failed, I thought I had messed up, but then I realized I could change things and try again. That made me feel like I could actually do engineering.”

“I used to get frustrated when I didn’t get something right the first time, but now I understand that fixing mistakes is part of the process.”

Theme 3: Making practices connected engineering with real-world settings.

This theme described that the participants began to recognize how engineering skills connected to their real-life problems. Most students noted that they had never considered engineering relevant before but were now more open to exploring engineering education and career opportunities.

“I didn’t think engineering had anything to do with my life, but now I see how it helps solve my problems.”

“This was the first time I could see myself doing something like this in the future.”

Conclusions

The findings of this mixed methods study showed that incorporating 3D printing in engineering education for rural students significantly enhanced their perceived engineering self-efficacy. A synthesis of quantitative and qualitative results suggested that embedding 3D printing within rural education offers a promising, hands-on approach to cultivating students’ self-perception as capable engineers and developing their confidence and persistence in problem solving through an iterative learning cycle. In addition, by emphasizing its real-world connection and community impact, 3D printing experience can foster rural students’ engineering career aspirations, which may further contribute to the effort in closing the nationwide gap in engineering workforce.

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