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Board 316: Innovation Self-Efficacy: Empowering Environmental Engineering Students to Innovate

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Abstract

This project evaluates if and how an intervention to design a K-12 STEM activity related to water chemistry impacts the innovation self-efficacy (ISE) of junior students enrolled in a required environmental engineering course. ISE is defined as having five behavioral components: questioning, observing, experimenting, idea networking, and associational thinking. In this course, the K-12 STEM activity is designed with a team of 3 to 5 students. The activity requires that the students develop an innovative activity that demonstrates environmental engineering concepts such as acid mine drainage, ocean acidification, and contaminant removal. The student projects are scaffolded throughout the 10 weeks via intermediate submissions and meetings with a K-12 STEM teacher and design mentors. In fall 2022 a pilot of the study was conducted and relied on a quantitative survey instrument that measured ISE, innovation interest (INT), and future innovative work interest (IW). Based on the preliminary findings of factor structure, item reliability, and face validity evaluated by two faculty and two undergraduate students, small changes were made to the quantitative assessment instrument. The revised survey was deployed in the fall of 2023 in a required junior-level test course and a senior-level control course. The senior-level control course consisted of students who took the junior-level course with the K-12 STEM activity in the previous year. In 2023 the K-12 STEM activity intervention also included additional scaffolding through the addition of 3 team-based and 2 individual reflections to understand the process of ISE formation. Pre-post comparisons of the quantitative survey items will be conducted for individual students in the test and control courses. Team and individual reflections from the test course will be analyzed after the course. Potential demographic differences in ISE will be explored. Potential team-level influences will also be evaluated to understand the impact of a team's ISE score on enhancing an individual team member's ISE gain. Focus groups and individual interviews with students who participated in the test course will take place in spring 2024. The ISE, INT, and IW of environmental engineering students will be further assessed in spring 2024 through the ISE survey in the environmental engineering capstone design course and a junior-level creativity and entrepreneurship design course. This assessment will compare two different learning experiences on ISE, INT, and IW, the K-12 STEM education activity design with a semester-long, group-based technical design experience. Preliminary results will be presented in the NSF Grantees Poster Session.

Introduction

Education for innovation is increasingly recognized as vital in today's world, with numerous studies highlighting its significance [1-4]. Innovation is essential for addressing the Grand Challenges in environmental engineering identified by the National Academies [5]. While innovation can take various forms, it typically involves introducing new or significantly improved products, services, or processes to the market [6]. In engineering education, innovation is often associated with creativity and entrepreneurship, with programs aiming to cultivate future innovation leaders [3,7]. Research has shown strong correlations between students' self-rated innovation skills and abilities and factors such as creativity, product development, start-up processes, leadership, and financial value [8]. However, the characteristics and behaviors associated with innovation may vary across industries, job types, and disciplines. Dyer et al. [9] identified questioning, observing, networking, and experimenting as key innovative behaviors, which may manifest differently depending on the context. Additionally, different types of innovation, such as technological, product, and process innovation, may be emphasized in various engineering disciplines [10]. In the context of environmental engineering education, a previous study demonstrated that engaging undergraduate students in designing K-12 STEM projects related to course outcomes led to increased innovation self-efficacy [11].

Building on that research, we examined the addition of mentors in fall 2022 [12]. Mentoring has been recognized as a potential mechanism for enhancing innovation self-efficacy, as evidenced by previous studies in various settings [13-14]. The intervention involved designing K-12 STEM projects related to water chemistry, with the addition of mentors to assist students during the project. Pre- and post-surveys were administered to assess changes in students' innovative attitudes. The results showed a modest increase in innovation self-efficacy post-intervention, but no significant changes in innovation interests or career goals. Additionally, the study compared data from 2021 and 2022, indicating that while there was no notable impact on innovation self-efficacy from enhanced mentoring, there were increased levels of product and process innovation in the 2022 cohort. Our pilot study acknowledged limitations such as the optional nature of mentor meetings and the fact that identifiers were not collected so paired comparisons of pre and post ISE could not be made. This is important because different numbers of students completed the pre and post-surveys.

The updated curricular intervention in fall 2023 included: (1) required meetings with the K-12 STEM and engineering design mentors, and (2) a series of short individual and group reflective memos during the semester. In addition, the IRB (Protocol # 23-0388) was revised to allow the collection of identifiers so that paired comparisons could be made between pre and post-survey responses.

The fall 2023 research aims to answer the following research questions:

1. How do the innovative attitudes of students enrolled in an environmental engineering course change after completing an open-ended team project to design a lesson to teach a water chemistry concept to K-12 students?
2. In what areas are the male and female students’ innovation self-efficacy similar and different?
3. To what extent do team dynamics impact engineering students’ innovative self-efficacy?
4. Does the innovative attitudes evidence in students’ reflective memos align with the innovation self-efficacy survey findings?
5. To what extent are innovative self-efficacy of neurodivergent and neurotypical engineering students similar and different?

Summary of Findings from the Curricular Intervention: Fall 2023

This phase of the study focused on evaluating the impact of a curricular intervention involving designing K-12 STEM projects related to water chemistry on students' innovative attitudes, particularly innovation self-efficacy. The research questions aim to understand how students' innovative attitudes changed after completing a team project while completing reflective memos on innovative attitudes. The study involved administering pre- and post-surveys to students and implementing a 10-week project where teams designed K-12 STEM activities. Mentors, including design mentors and K-12 STEM mentors, were introduced to assist students during the project. The courses included three team reflective memos (mapped to questioning, experimenting, and networking innovative behaviors) and two individual reflective memos (mapped to observing and networking innovative behaviors). The reflective memos were short (100-200 words) but intended to anchor students in innovative behaviors. The survey instrument included aspects such as innovation self-efficacy, innovation interests, and career goals related to innovative work. The wording of a few survey items was changed compared to 2022 after face validity discussions with two engineering students and two engineering faculty. In addition, the survey response options were changed to a 1 to 7 scale (in 2021 and 2022 the scale was 1 to 5 with a preferable not to answer option). The survey responses will be analyzed to assess changes in students' attitudes.

Among 45 students enrolled in the course, 37 completed the pre-survey and 39 completed the post-survey, with paired data for 35 students. A brief look at the data (without pairing) found an increase in innovation self-efficacy (ISE average pre 4.0+0.9 to post 4.7+0.8, unpaired t-test $p<0.001$), and no changes in innovation interests (average pre and post 5.2) or innovative work goals (average pre 5.0 and post 5.1). On the pre-survey female students had lower ISE than male students (average 3.7 vs. 4.4, p 0.04) but there was not a significant difference on the post-survey (4.6 vs 4.9, p 0.20). In addition, results can be analyzed for 7 teams (out of a total of 11 teams in the class) because all team members consented to participate in the research. On the pre-survey, the average ISE of the students on each team varied from a low of 3.4 to a high of 4.6. On the post-survey, the average ISE of the students on each team varied from a low of 3.8 to a high of 5.3; the average increase in ISE ranged from 0.4 to 1.1. In our post-survey, 7 students self-identified themselves as being neurodivergent (ND), 4 students declared maybe neurodivergent, and 29 students declared being neurotypical. Amongst those who declared being or maybe ND, the average pre-survey scores were 3.6 for ISE, 5.3 for INI, and 4.7 for IW. In the neurotypical participants, the average pre-survey scores were 4.1 for ISE, 5.1 for INI, and 5.1 for IW.

In conclusion, this phase of the study highlights the importance of education in fostering innovation in engineering and provides insights into the potential effects of reflection and mentorship on students' innovative attitudes and behaviors. The results will suggest avenues for future research to explore the relationship between innovation self-efficacy and product/process innovation more directly.

Future Work

Our final round of data collection is from focus groups with research participants in the curricular intervention which was conducted in fall 2023. Furthermore, the reflective memos and pre/post ISE survey data of fall 2023 from the participants need to be analyzed with regards to the demographics to understand how they informed the innovation self-efficacy of the engineering students.

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