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Board 140: Work in Progress: Exploring Innovation Self-Efficacy in Neurodiverse Engineering Students

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Abstract

It is critical to incorporate inclusive practices in the engineering curriculum which prepares neurodiverse students to achieve their full potential in the workforce. This work-in-progress paper seeks to capitalize on the unique strengths of marginalized neurodiverse engineering students. In this study, the innovation self-efficacy of engineering students who self-identify as neurodiverse is explored before and after a curricular intervention, which has been shown to have the potential to enhance innovation self-efficacy, in an environmental engineering target course. A previously validated Likert-type survey was used, which included the Very Brief Innovation Self-Efficacy scale, the Innovation Interests scale, and the Career Goals: Innovative Work scale. Among the 47 responses on the pre-survey, 13% of the students self-identified as neurodiverse and an additional 19% indicated that they were maybe neurodiverse. This included a much higher percentage of female than male students in the course (23% vs. 5% neurodiverse). There were no significant differences in the pre-survey or post-survey in the innovation self-efficacy and innovation interest among students who self-identified as neurodiverse, maybe neurodiverse, and not neurodiverse. Career goals based on the innovative work scale differed in the pre-survey among the three groups, being lowest among students who self-identified as maybe neurodiverse; there were no differences among the groups in the post-survey. It appeared that there were gains in the innovation self-efficacy between the pre and post-survey among the students who self-identified as neurodiverse and maybe neurodiverse but these differences were not statistically significant. A limitation of the study was the lack of ability to pair the data for individual students and a low number of neurodiverse students in the dataset. This preliminary work calls attention to the need to consider neurodiverse students in our instructional practices. In the future, we hope the research will expand our understanding of a neurodiverse-friendly curricular design in preparation for engineering students with autism spectrum disorder and other types of neurodiversity for the workforce, as well as assisting engineering educators in the adoption of practices that have the tendency to enhance innovation self-efficacy in neurodiverse students.

Background

Neurodiversity (ND) represents diverse ways that minds and brains function. ND may include medical conditions such as autism spectrum disorder (ASD, previously known as Asperger's syndrome), attention-deficit hyperactivity disorder (ADHD), dyslexia, mental health conditions including bipolar disorder, social anxiety, and others. Using the term neurodiverse avoids a deficit perspective and disabling discourse, recognizing an intersection between medical differences and social constructs (Rappolt-Schlictmann *et al*., 2018; Jaarsma and Welin, 2012; Dwyer, 2022).

ND may pose difficulties in some situations while imparting benefits in others (Fung *et al*., 2022). For example, ND has been framed as an advantage in the workforce (Austin and Pisano, 2017). Previous research specifically on ADHD found high divergent thinking (Taylor *et al*.,

2020) and higher originality, novelty, and flexibility (White and Shah, 2016). These attributes appear well aligned with the importance of innovation and creativity in engineering. However, it is of concern that college may not be supporting the success of neurodiverse students. The University of California found that ND students had a lower graduation rate compared to students without disabilities (UC 2021). In engineering ADHD characteristics "negatively predicted engineering GPA" (Taylor et al., 2020).

The extent of neurodiversity among college undergraduates, STEM undergraduate students, and/or engineering undergraduate students have not been well characterized. The issue is complicated by the range of medical conditions that are included, diagnosis or lack of formal diagnosis, disclosure, and medical privacy. However, for general context, the Centers for Disease Control and Prevention estimate that 13% of children 12-17 years old have been diagnosed with ADHD (US CDC, ND). Boys are more likely to be diagnosed with ADHD and ASD than girls (US CDC, ND), and diagnosis also varies with race/ethnicity.

Overall, there is a desire to learn more about neurodiverse students in engineering, and in particular to characterize their attitudes toward innovation.

Research Questions

This exploratory research was aimed at evaluating the following questions:

1) Do engineering students who self-characterize as neurodiverse have different: innovation self-efficacy, innovation interests, or innovative work?
2) Do these innovation attitudes differ at the end of the semester among students who participated in an open-ended activity that may impact innovation attitudes?

Methods

The study was conducted under a protocol approved by the local Institutional Review Board (IRB) for Human Subjects Research (Protocol #21-0473). This pilot study was conducted within a single engineering Water Chemistry course taught at the University of Colorado Boulder in the Fall of 2022. The course is required for students majoring in environmental engineering and is typically taken in the junior year. Students from other majors including civil engineering may also enroll. During the fall semester, students worked in (self-selected or instructor-assigned) teams of 4 to 5 students on a 10-week-long class project. The open-ended project required students to design an activity that would teach principles of water chemistry to K-12 students. The specifics of the intervention are described in [Bolhari and Tillema, 2022]. The first author of the paper was the instructor for the course.

The timetable for the curricular intervention is depicted in Figure 1. The heart of curricular intervention was a 10-week class project where students were grouped up into thirteen teams (eleven teams of 5 students and two teams of 4 students).

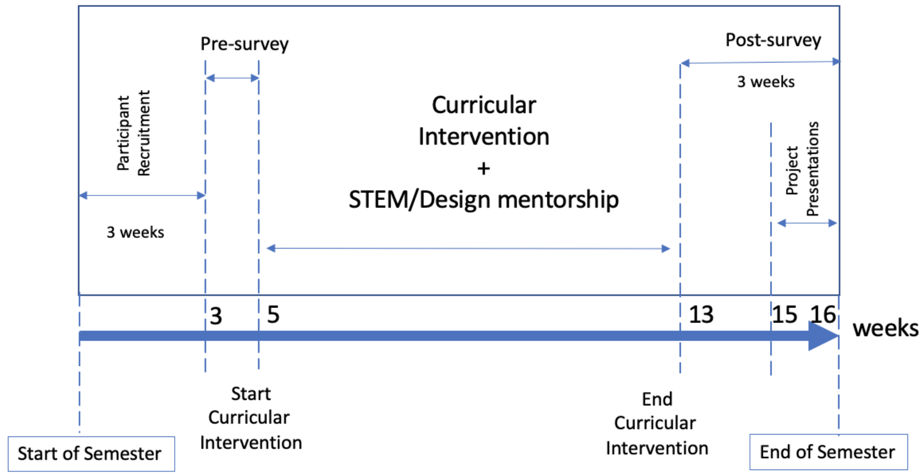

Figure 1- Timeline of the curricular intervention design and mentorship.

The start of the intervention posed an open-ended, hands-on, team-based design project where students were asked to: 1) Design a K-12 STEM activity of their choosing using Water Chemistry principles, for a target grade or a range of grades. Students were offered extra credit for creating video demonstrations of their lessons and experiments for STEM teachers' classroom use; 2) Seek written input from their Design Mentor by week 8. Two Design Mentors were project consultants from the University of Colorado Boulder and were introduced to the class in week 5. Students were encouraged to utilize the Idea Forge makerspace and the water chemistry lab for setting up their projects; 3) Seek written input from their STEM Education Mentor by week 8. The STEM Mentor was a K-12 STEM teacher, recruited from our local public school district, and was introduced to students in week 5. The STEM Mentor assisted students in the design of developmentally appropriate content for the target grade or the range of grades; 4) Align their activity with either of these K-12 educational STEM standards: Common Core State Standard, Next Generation Science Standards (NGSS), or International Technology and Engineering Educators Association (ITEEA) Standards for Technological Literacy (STL); 5) Map out their activity to be hosted on '*TeachEngineering'* digital library to reach a global audience. *TeachEngineering* is a standards-aligned, free-access curricular resource aimed at engaging students in exploring real-world engineering and engineering design principles focused on K-12 engineering education and offers more than 1,800 lessons and hands-on activities contributed by 57 contributors (including 40 National Science Foundation (NSF) funded GK-12 and Research Experience for Teachers (RET) engineering education grants) and with over 3.5 million users annually (TeachEngineering, 2023). The students had the opportunity to pursue classroom testing of their designed activities and lesson-plan publication with *TeachEngineering* after the intervention (after the post-survey) unless they notified the course instructor to object to this pursuit.

Survey Instrument
The survey instrument began with an informed consent statement. This was followed by 15 items to measure attitudes toward innovation. The instrument is derived from Schar *et al*. (2017) and has been previously described [Bolhari and Tillema, 2022]. The instrument is summarized in Table 1. Note that there were 6 numbered response levels for each of the 15 items. The scale was anchored using the words "prefer not to answer" (PNA) on the left and "extremely …" on the right. This differs from the survey which was previously characterized for validity and reliability and located the PNA option set apart from the Likert-type scale items of 1 to 5 which had 'not confident' as the wording anchor at 1 to 'extremely confident' as the wording anchor at 5. This change was due to the question style limitation of the Google form. The form allowed students to skip any of the items they would like.

Table 1. Synopsis of Innovation Evaluation Survey

Construct	Number of items	Item wording / example	Response scale
Innovation self-efficacy	5	Think about how confident you are in your ability to do these activities (e.g., generate new ideas by observing the world)	1 to 6 extremely confident
Innovation interest	4	How much interest do you have in ____ (e.g., experimenting in order to find new ideas)	1 to 6 very high interest
Innovative work	6	How important is it to you to be involved in the following job or work activities in the first five years after you graduate? (e.g., generating creative ideas)	1 to 6 extremely important

At the end of the survey after the items measuring students' attitudes related to innovation, there were three demographic items. The first asked students "Do you identify as being neurodiverse (an individual with difference in brain function and behavioral traits, e.g., autism spectrum)?" The response options provided were yes, no, and maybe. Next students were asked, "which gender do you identify with?" Students were provided with 5 options: non-binary, transgender, female, male, or other. The final survey item was "Which of the following best describes you?" Students were allowed to select among 7 options that describe race/ethnic groups.

The survey intentionally did not have the students provide individually identifiable information to ensure that they were fully confident of anonymity, and to avoid pressuring the students to participate in the study based on the fact that the PI of the study was in a position of power as their course instructor. This prevented pairing the pre- and post-responses, which is a significant limitation of the pilot study.

Survey Administration
The survey items were administered via an online Google form and the participants were invited via email. The primary author was the instructor of record for this course and as a result, an independent third party with no power or authority over the students was recruited to administer the pre/post surveys. The pre-survey was administered on week 8 of the semester and it did not require students to answer all items. The only required question to answer was the consent to participate in the study. The post-survey at the end of the term (in weeks 14 and 15).

Respondents
There were 63 students enrolled in the course, and the response rate was 75% on the pre-survey and 63% on the post-survey. The demographic characteristics self-reported by the survey respondents are summarized in Table 2. On the pre-survey, 13% of the respondents identified as neurodiverse, and an additional 19% indicated that maybe they were neurodiverse. The uncertainty could be due to a lack of clarity of what met the criteria, and/or lack of official diagnosis. Interestingly, female students were much more likely to self-identify as neurodiverse than male students (Table 3).

Table 2. Demographic information on survey respondents

Characteristic	**2022 pre**	**2022 post**
Course enrollment	63	63
N survey respondents	47	40
Response rate, %	75%	63%
Identify as neurodiverse?		
% Yes	13	17.5
% maybe	19	20
% No	68	62.5
Gender:		
% male	47 (5% ND, 9% maybe, 86% no)	35
% female	47 (23% ND, 23% maybe, 55% no)	50
% non-binary	4 (100% maybe)	10
% transgender	2 (100% no)	5
Race/Ethnicity ^		
% White/C	70	73
% Hisp/Latinx	15	8
% Multi/Biracial	11	13
% not listed	4	8

^ Asian or Pacific Islander, Native American or Alaskan Native, Black or African American were listed as options, but no students selected these

Data Analysis
After characterizing the demographics of the respondents, the first step in data analysis was to explore the individual responses. On the pre-survey, 1 response was removed from the dataset, because 4 of the 15 innovation items were rated as 'prefer not to answer' (PNA); the majority of the other respondents had complete responses or no more than 1 PNA answer per construct.
Table 3. Gender and race/ethnicity characteristics of different groups of students based on their self-characterized neurodiversity: pre-survey.

	Yes, neurodiverse (n=6)	Maybe (n=9)	No (n=32)
Gender:			
% male	17	22	59
% female	83	56	38
% non-binary	0	22	0
% transgender	0	0	3
Race/Ethnicity ^			
% White/C	67	56	75
% Hisp/Latinx	33	22	9
% Multi/Biracial	0	11	12.5
% not listed	0	11	3

^ Asian or Pacific Islander, Native American or Alaskan Native, Black or African American were listed as options, but no students selected these

This respondent reported themselves as not neurodiverse and Transgender. On the post-survey 2 responses were fully removed from the dataset; these had 15 and 6 PNA responses on 15 items (both not neurodiverse); 1 respondent (neurodiverse) was removed from the Career construct (3 PNA of 6 items). Next, the PNA responses (1) were deleted individually from the remaining individuals, to avoid confounding the data. Next, the responses within each construct were averaged, resulting in a score on a scale of 2 to 6.

To explore potential differences between ND groups and the pre/post survey, t-tests were conducted in Excel. While non-parametric tests would be more appropriate since the data are not continuous, other studies have found that t-tests are generally robust to violations in these constraints (Norman 2010; Sarle 1995). Across the 15 individual survey items, the skewness and kurtosis of the data ranged from 0.6 to -1.3 (average -0.3) and 2 to -1.2 (average -0.1), indicating that the responses were not significantly non-normal.

Results

The findings of the pre-survey are summarized in Table 4. There were no statistically significant differences among innovation self-efficacy and innovation interest among the ND groups. A t-test found a significant difference in career interest among yes ND vs. maybe ND, and maybe ND vs. not ND students. In addition to the average across the items comprising a construct, the 3 items with the largest differences are shown.

Table 4. Survey Findings: Average and standard deviation (2 to 6 scale).

	Pre-survey			Post-survey		
	Yes ND (n=6)	Maybe (n=9)	No (n=31)	Yes ND (n=7)	Maybe (n=8)	No (n=23)
Self-efficacy (avg 5 items)	4.3 + 0.9	4.5 + 0.7	4.4 + 0.5	4.7 + 0.6	4.9 + 0.7	4.6 + 0.8
Innovation Interest (avg 4 items)	4.7 + 0.7	4.4 + 0.8	4.4 + 0.5	4.4 + 0.9	4.9 + 0.6	4.5 + 0.9
Career Goals (avg 6 items)	4.9 + 0.7	4.2 + 0.7	4.6 + 0.7	4.6 + 1.0	4.5 + 0.9	4.6 + 0.8
Selling a product or service in the marketplace.	3.8 + 1.5	2.4 + 0.8^	3.7 + 1.3	3.7 + 1.6	3.7 + 1.5	4.1 + 1.1
Giving an elevator pitch, finding resources to bring new ideas to life.	3.8 + 1.5	2.9 + 1.3	3.9 + 1.2	3.3+ 1.5	3.6 + 1.3	4.1 + 1.4
Experimenting in order to find new ideas.	5.3 + 0.5	4.9 + 0.9	4.5 + 0.9	5.0 + 1.4	5.6 + 0.7	4.6 + 1.0

^ n=7, because 2 responses were PNA; + n=8 because 1 response PNA

The post-survey data are also summarized in Table 4. There were no statistically significant differences across the three innovation constructs when different ND groups were compared. Comparing the pre and post-survey results, it appears that innovation self-efficacy was higher in the post-survey among the students who self-identified as neurodiverse and maybe neurodiverse. However, these differences were not statistically significant (difficult to detect given the low number of students). Note that it cannot be verified whether the same students took both the pre and post-surveys.

Implications of Our Findings

The totality of our findings reveals that neurodivergent engineering students were not significantly different from their peers in their levels of innovation self-efficacy, innovation interest, or career motivations toward innovative activities at work. However, ND students may have more interest in 'experimenting in order to find new ideas' compared to their peers.

First, as it relates to engineering education instructional practices, educators would do well to adopt specific practices that reinforce neurodivergent students' motivation to persist in the engineering major through affirming efforts that close the disconnect between student's aspiration to pursue engineering and the sense that they are losing motivation to persist in the major. Examples of affirming practices include meaning-making that connects students' present experiences or students' personal values to their future selves (Ling-Siegler *et al*., 2016) and develops their self-efficacy (Chyung *et al*., 2010; Colbeck *et al*., 2001; Ponton *et al*., 2001). Moreover, educators can potentially leverage engineering students' innovation self-efficacy through team-based, project-based work that examines real-world contexts of engineering applications. When carefully designed, those experiences can foster students' sense of belonging (Taylor & Hernandez, 2022; Buckley *et al*., 2019).

Second, as it relates to engineering curricula, we recommend that engineering programs quantify the number and types of neurodivergent students. Identification of our neurodivergent student assets can then motivate the degree to which that engineering program requires adaptation to support these students, such as cohorts, space/dorms, etc. Beyond this, it also gives insights to how interactions with others may affect the confidence and self-efficacy of neurodiverse students in the major, particularly as interventions are designed and deployed. Low self-efficacy has been linked to low retention rates in programs, particularly for Students of Color, so a measurement of social capital, as an example, is a way for a program to address issues in retention and align opportunities for students of color with goals of improving relations and confidence.

Limitations

It is uncertain how students self-defined neurodiverse when they were answering the demographic question. The term neurodiverse isn't particularly widely used and families. Further, given the short parenthetical description, students may have been uncertain about any medical conditions or mental health issues that are typically associated with neurodiversity but beyond the single example provided of the autism spectrum. In the future, additional examples should be provided, particularly ADHD which is perhaps very common among college students. Another challenge of the study is that even if neurodiverse thought patterns provide advantages for creativity and innovation, individuals may not recognize those abilities (translated to their confidence) nor particularly enjoy or be interested in those roles. Previous work has certainly found that confidence ratings are suspect in terms of correlating to actual abilities, subject to bias including the Dunning-Kruger effect (Dunning *et al*., 2004 and Schlosser *et al*., 2013) and under-confidence among females (Marshman *et al*., 2018). A previous study also found lower self-efficacy among adults with ADHD (Newark *et al*., 2016). Another consideration is whether the characteristics of innovation might manifest differently among different individuals, and in particular among neurodiverse individuals.

The pilot survey did not collect personal identifiers, preventing pairing pre and post-survey responses; this paired data is important if the research hopes to clearly identify changes over time (which may be due to the intervention). The small number of respondents limited the ability to detect differences among demographic groups. Thus, future work might use semantic analysis, which previously found differences among a fairly small sample of college students with and without ADHD (White and Shah 2016). Future research should also consider intersectional effects (e.g., Farquhar-Leicester et al. 2022).

Our findings are likely limited by the response rate and sample size of our study. Our pilot study recruited 47 survey respondents on the pre-survey and 40 on the post-survey, which is a small sample size and presents a challenge for statistical treatments. Moreover, the small sample size makes it challenging to elicit the survey dimensions (innovation self-efficacy, innovation interests, and career goals for innovative work) in smaller demographic groupings.

Summary and Conclusions

According to the National Science Foundation (NSF, 2023), the composition of learners has become increasingly diverse in engineering classrooms and engineering practice, meaning that engineering instructional practices must evolve to leverage the existing skills and knowledge of the increasingly diverse population of students enrolled in the engineering classroom. Our exploratory study sought to measure those skills and knowledge in engineering students through the lens of Innovation Self-Efficacy (ISE). We deployed a 15-item survey and distributed it to engineering students in one junior/senior level environmental engineering course at University of Colorado Boulder. The survey sought to explore neurodivergent engineering students' innovation self-efficacy. We found that the innovation attitudes of the neurodivergent engineering students were not significantly different than peers that did not self-identify as neurodivergent. This study represents preliminary research to understand how to strengthen neurodivergent engineering students' innovation self-efficacy as they develop into engineers.

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