Board 347: Positive Predictors of Neurodiverse Students' Sense of Belonging in Engineering

Dr. Maria Chrysochoou, University of Connecticut

Maria Chrysochoou is a Professor and Head of the Department of Civil and Environmental Engineering at the University of Connecticut. She obtained her BS in Physics at the Aristotle University of Thessaloniki, her MS in Environmental Engineering at Technis

Rachael Gabriel, University of Connecticut
Ms. Connie Syharat, University of Connecticut

Connie Syharat is a Ph.D. student and Research Assistant at the University of Connecticut as a part of two neurodiversity-centered NSF-funded projects, Revolutionizing Engineering Departments (NSF:RED) "Beyond Accommodation: Leveraging Neurodiversity for Engineering Innovation" and Innovations in Graduate Education (NSF:IGE) "Encouraging the Participation of Neurodiverse Students in STEM Graduate Programs to Radically Enhance the Creativity of the Professional Workforce". As a graduate researcher, she is conducting qualitative research related to the experiences of neurodiverse graduate students in STEM fields. Previously, she spent eight years as a K-12 teacher in Connecticut, where she maintained a focus on providing a varied learning environment and differentiated instruction for all types of learners. She is currently pursuing a doctoral degree in Engineering Education in UConn's College of Engineering.

Dr. Christa L. Taylor, University of Connecticut

Christa L. Taylor, Ph.D., is an Independent Research Consultant and Research Affiliate with the Department of Educational Psychology at the University of Connecticut. Her research is focused on issues in creativity, social cognition, and neurodiversity. She received a Ph.D. in Social-Personality Psychology from the University at Albany, State University of New York before completing postdoctoral work at Yale University and Université catholique du Louvain in Belgium.

Positive Predictors of Neurodiverse Students' Sense of Belonging in Engineering: An Analysis of Student Survey

Abstract

Recent literature points toward the benefits of cognitive diversity in building a more creative engineering workforce. Still, despite the potential of neurodiverse individuals, such as autistic students, students with ADHD and/or dyslexia to leverage their unique assets to contribute to innovative solutions to engineering problems, they remain highly underrepresented in engineering majors. Thus, a department-level initiative was established as part of a National Science Foundation Revolutionizing Engineering Departments (NSF:RED) grant at a large, research intensive (R1) institution to foster a radically inclusive culture that enhances the participation and sense of belonging of neurodiverse students in engineering. The purpose of this study, conducted in the fourth year our of five years in the project, was to identify the predictors of students' sense of belonging in engineering, assessing both classroom experiences in department courses and out-of-classroom experiences. A survey related to student experiences in engineering courses was administered and data from 144 respondents were included for analysis. Factor analysis identified five classroom-specific factors (engagement, instructional quality, inclusion, learning development, and disengagement) and two out-of-classroom influencing factors (belonging and community access). Multiple regression models and independent sample t-tests were employed to determine the significant predictors of sense of belonging in engineering. The study found that classroom inclusion was the only significant predictor of belonging and could predict it positively to a moderate degree. Further, it was found that students in revised inclusive courses reported significantly stronger feelings of inclusion and belonging than their peers in traditional courses. These findings suggest that systematic efforts to implement neuroinclusive learning practices in engineering education may contribute to a sense of belonging for all students.

Introduction

The concept of neurodiversity, a term coined by sociologist Judy Singer [1], emerged as members of the autistic community challenged the predominant disability framing of autism and embraced the notion that diversity of minds is both beneficial and crucial for the survival and adaptation of human societies. This term is now often used as a term that encompasses a range of neurological variations in human populations. While much research into these cognitive variations continue to frame such differences as deficits or disorders, a growing body of research indicates that neurodiverse individuals such as autistic students, and students with attention deficit hyperactivity disorder (ADHD), or dyslexia, may possess strengths that are considered assets in engineering and other STEM fields, such as creative thinking [2]-[5], visual-spatial skills [6]-[8], and pattern recognition [9], [10]. However, the recruitment and retention rates of neurodiverse students in engineering programs remain low [11], [12]; traditional teaching methods and an overfocus on student deficits contribute to a learning environment that may neither meet the needs of neurodiverse students nor succeed in harnessing the strengths that these students bring to the table. Thus, a department-level initiative was established as part of a National Science Foundation Revolutionizing Engineering Departments (NSF:RED) grant at a

large, research intensive (R1) institution to foster a radically inclusive culture that increases the participation and enhances the sense of belonging of neurodiverse students in engineering.
A sense of belonging has long been recognized as a fundamental human need [13], [14]. In the higher education context, Tinto's theory of departure emphasizes the importance of both social and academic integration for persistence [15]. The literature related to the persistence of underrepresented groups supports the idea that students' sense of belonging and formation of engineering identity are key aspects that contribute to retention in undergraduate STEM programs [16], [17]. As Tonso [18] writes, "Engineers' identification with their profession can be critical for persistence, both as a student and then as a professional" (p. 267). In other words, if undergraduate students feel that they are "not cut out" for engineering, they will be less likely to complete their program.

The culture within engineering education programs may create a learning environment in which neurodiverse students struggle to feel that they belong [19]. First, engineering programs are often characterized by standardized ways of thinking and problem solving and traditional modes of instruction and assessment [20], [21]. Neurodiverse students, whose ways of thinking, learning, and socializing may differ from the perceived norm, may struggle to engage in STEM classes that favor a traditional approach to teaching and learning; the fast pace of instruction and large class size, especially in large universities may exacerbate these challenges [22]. In higher education, across the board, neurodiverse students experience high levels of anxiety and stress, social challenges, and a perceived lack of support, despite institutional structures including academic accommodations and mental health services [23]. The predominant culture in STEM fields may further contribute to these challenges due to its competitive environment and large introductory "gatekeeper" courses that weed out many within the first few semesters [24]. Additionally, student-centered teaching strategies, such as active or problem-based learning that may enhance learning for neurodiverse students, have not been adopted widely across STEM classrooms [25], [26]. Rather, classroom instruction in many schools of engineering depends on passive learning *via* lecture [27]. Unsurprisingly, neurodiverse students enroll in STEM courses at a lower rate than other underrepresented groups and many do not persist as they progress beyond the first year [28].

Thus, the formation of engineering identity may be critical for neurodiverse students, who may be particularly likely to feel that they do not belong in engineering or other STEM fields. Some students are explicitly discouraged by faculty from pursuing their chosen major or using their accommodations [29]. All in all, the stigma of disability labels from faculty and peers add to students' lack of disclosure and failure to request accommodations [30]-[33]. Studies show that engineering faculty are often less willing to provide students with academic accommodations than those in other departments [33]. This is supported by one study of undergraduate engineering students in which it was found that only 17.6% of participants who were formally diagnosed with ADHD were receiving services from the university's Center for Students with Disabilities [4]. Students perceive that when accommodations are granted, they are seen as unfair by their peers, and they are often questioned by faculty who see accommodations as unnecessary or as a burden [31], [33].

Collectively, these obstacles contribute to an environment in which neurodiverse students do not feel safe to disclose their diagnosis or experiences, and thus remain an invisible minority whose needs are often not met and strengths go unrecognized. Additional factors may influence the visibility or invisibility of neurodiverse students, as understandings and experiences of neurodiversity vary widely across social groups. For example, women and girls are often diagnosed later in life than men or boys, and are frequently diagnosed with anxiety or depression, while their ADHD or autism remains unrecognized [34], [35]. Different cultural understandings of cognitive differences, along with biases and obstacles embedded within the diagnostic criteria may contribute to disparities in rates of diagnosis and/or identification with neurodiversity. It has been noted that individuals from racial or ethnic minorities are less likely to receive a neurodiversity-related diagnosis such as ADHD or autism or to access supports than their white peers [36]-[40]. The invisibility of a large number of neurodiverse students thus adds a particular challenge in understanding this population, as many neurodiverse students either do not have a diagnosis, or do not wish to disclose it in the higher education setting.

Project Overview and Context

The NSF:RED project activities span the entire experience of the undergraduate student engineering experience, including recruitment and transition into the engineering program, community building, transforming teaching and learning, holistic support and advising, and providing career support as students prepare to join the work force. This paper focuses on one key area of the project: the department's efforts to transform teaching and learning through the redesign of core courses within the department, creating an inclusive learning environment in which all students may thrive. Efforts were aimed at enhancing the inclusivity of engineering courses for neurodiverse students through cultural change (i.e., building a culture of inclusion via strengths-based messaging), instructional design (i.e., alignment of course components, adoption of inclusive teaching strategies, multiple modes of assessment, etc.), structured supports, and personal connections [41]. As previously noted, a large number of neurodiverse students are unidentified, as they have either not received a diagnosis or they choose to not disclose it in the educational setting. Rather than target interventions for the subset of students who self-identify as neurodiverse in engineering classrooms, larger-scale environmental change was implemented through the integration of neuroinclusive teaching practices, with the aim of enhancing the learning environment for *all* students.

Within the context of this project, the course redesign process is guided by a set of faculty-created standards for neuroinclusive teaching, known within the project as I-Standards; these standards have undergone multiple iterations to reflect the team's understanding of current best practices. The standards were developed along with experts from the university's Center for Excellence in Teaching and Learning and the School of Education. Anchored in a strengths-based approach to neurodiversity, the standards focus on three main areas: 1) building a culture of inclusion, 2) instructional design and inclusive teaching practices, and 3) enhancing communication and supports for students [41]. The teaching and learning standards are well aligned with existing standards such as Universal Design for Learning (UDL), which has been found to be a helpful factor that increases the accessibility of the STEM curriculum and supports student success [33]. By providing multiple means of representation, multiple means of engagement, and multiple means of action and expression, instructors build flexibility into instruction to minimize barriers to learning and meet individual needs [42].

The I-Standards encourage instructors to develop of a culture of inclusion by a) including a written inclusion statement in the course syllabus that uses strengths-based language related to neurodiversity and goes beyond the required accessibility statement related to access and accommodations; b) faculty participation in professional development learning activities related to neurodiversity; and c) incorporation of inclusive teaching practices that are appropriate for their course. Standards for neuroinclusive teaching and learning focus on a) instructional design (such as alignment of course components), b) accessibility of course materials, c) personalization via choice and flexibility, and d) incorporation of active learning and real-world applications in regular class activities. Finally, the standards related to communication and supports encourage instructors to a) build in mechanisms to receive student feedback about the course, b) provide feedback on student performance in multiple modes (i.e., narrative, oral, numerical), c) build in supports for underperforming students, and d) foster personal connections with students within and outside of the classroom. Throughout, the commitment to a strengths-based approach may enhance student motivation and engagement [43]-[45] as instructors provide multiple modes for activities and assessments and provide flexibility that gives students the opportunity to make choices and apply their strengths within the context of their learning activities and assessments

This study examines the potential impact(s) of the implementation of neuroinclusive teaching practices in redesigned engineering courses, known within the project as Include Courses, or I-Courses. Specifically, the purpose of this study was to identify the predictors of students' sense of belonging in engineering, assessing both classroom and out-of-classroom experiences in department courses.

Methods

Survey Design and Implementation

The student survey was created by modifying select items from Schelly et al.'s [46] Student Perceptions of Faculty Implementation of Universal Design for Learning Survey and Glynn et al.'s [47] Science Motivation Questionnaire. Additional items were created based on the Include Project's I-Standards. Participants were asked to indicate how much they agreed with 27 statements about the course in which they were enrolled. The participants were recruited from both redesigned Include courses and conventional courses in the department. Example survey questions include, "*Instructor presents information in multiple formats*" and "*I can perform at my full potential in this class.*" A separate section of the survey asked participants to indicate how much they agreed with eight statements about activities outside of class related to engineering. For example, "*I can successfully participate in engineering activities that I am interested in*" and "*I feel welcome at engineering-related activities*." Response options for both sections of the survey were on a 5-point scale from 1 (strongly agree) to 5 (strongly disagree). Items were reverse scored for interpretability during analysis. Participants were also asked to indicate if they identified as either neurodiverse or a student with a disability and, if so, if they had formally requested academic accommodations through the university. The survey was shared with students via a Qualtrics link. 19 Professors in the Department of Civil and Environmental Engineering shared the Qualtrics survey link with students in their courses via email. 13 of the Professors taught traditional courses and six taught redesigned Include courses. Students who completed the survey were entered into a gift card drawing.

Data Analysis
Although 171 students completed the student survey, data for 27 students were excluded from analyses because they responded to more than 80% of scale items using a single anchor. Of the remaining 144 respondents, 26 indicated that they identify as either neurodiverse, or as a student with a learning or physical disability. Nine of these students reported that they had requested academic accommodation services through the Center for Students with Disabilities (CSD).

The factor structure of the student scale was examined using Principal Axis Factoring using the oblique rotation Promax with Kaiser Normalization. According to the number of eigenvalues greater than one and examination of the scree plot, five factors were clearly identified. Examining the pattern matrix of the rotation of the scale, the five factors could be labeled as follows: (1) engagement, (2) instructional quality, (3) inclusion, (4) learning development, and (5) disengagement. The eight items loading on the engagement scale reflect interest and enjoyment in the course. The eight items loading on the instructional quality scale reflect positive characteristics of the instructor and course, such as how responsive the instructor is to students. The five items loading on the inclusion scale reflect course accessibility and adaptability, as well as students' feelings of inclusion. The three items loading on the learning development scale reflect students' ability to engage in self-regulated learning behaviors. The two items loading on the disengagement scale reflect a lack of motivation and boredom. One item ("*I can perform at my full potential in this class*.") cross-loaded on the engagement and inclusion factors and was ambiguous for which factor it would be more theoretically meaningful. Therefore, this item was excluded from all factors.

Results and Discussion
A multiple regression model was used to determine if the five factors of the student scale predicted students' feelings of belonging in engineering. The model, wherein all predictors were entered simultaneously, was statistically significant, $F(5, 125) = 6.85$, $p < .001$, explaining 18% of the variability in belonging ($R2 = .18$, adj. $R2 = .22$). Inclusion was the only significant predictor of belonging, accounting for all other predictors in the model, and positively predicted feelings of belonging in engineering to a moderate degree ($\beta = .35$, $p = .002$).

One outlier ($Z > \pm 3.5$ SD from the mean) in the Include group was detected on the inclusion factor ($Z = 4.43$); The inclusion scale score for this participant was excluded from further analyses. Descriptive statistics for each group may be seen in Table 1. Mean scores did not differ between students in Include and Non-Include courses for engagement, $t(142) = 0.56$, $p = .57$, $d = 0.10$, 95% CI [-0.25, 0.45], learning development, $t(142) = 1.58$, $p = .12$, $d = 0.28$, 95% CI [-0.07, 0.63], or disengagement, $t(142) = -0.21$, $p = .83$, $d = -.04$, 95% CI [-0.38, 0.31]. Because Levene's test for homogeneity of variance indicated that scores for students in Non-Include courses demonstrated significantly greater variability than those in Include courses for inclusion ($F = 11.21$, $p = .001$) and instruction quality ($F = 8.88$, $p = .003$), Welch's t-test was used to examine group differences for these factors. Students in Include courses reported significantly greater inclusion ($M = 4.29$, $SD = .42$) than students in Non-Include courses ($M = 3.52$, $SD = .78$), $t(139.75) = 7.66$, $p < .001$, $d = 1.12$, 95% CI [0.75, 1.50]. Students in Include courses also reported significantly greater instruction quality ($M = 4.18$, $SD = .55$) than students in Non-Include courses ($M = 3.51$, $SD = .79$), $t(126.94) = 5.97$, $p < .001$, $d = 0.94$, 95% CI [0.58, 1.30].

For responses on the community scale, students in Include courses reported a significantly greater sense of belonging (M = 3.94, SD = .72) than students in Non-Include courses (M = 3.41, SD = .88), t(130) = 3.53, p = .001, d = 0.64, 95% CI [0.28, 1.01]. Students in Include courses also reported significantly greater access to community activities (M = 3.69, SD = .70) than students in Non-Include courses (M = 3.27, SD = .66), t(132) = 3.36, p = .001, d = 0.61, 95% CI [0.25, 0.97].

Table 1

Descriptive statistics for scale factors by course type.

	Course Type									
	INCLUDE					Non-INCLUDE				
Scale Factor	*N*	Mean	*SD*	Min.	Max.	*N*	Mean	*SD*	Min.	Max.
Student Scale										
Engagement	48	3.78	0.85	1.38	4.88	96	3.71	0.76	1.13	5.00
Instruction Quality[a]	48	4.18	0.55	2.38	5.00	96	3.51	0.79	1.00	5.00
Inclusion[a]	47	4.29	0.42	3.20	5.00	96	3.52	0.78	1.00	5.00
Learning Development	48	4.06	0.63	2.00	5.00	96	3.85	0.76	1.33	5.00
Disengagement	48	2.57	0.95	1.00	5.00	96	2.61	0.98	1.00	5.00
Community Scale										
Belonging[b]	47	3.94	.72	1.67	5.00	85	3.41	.88	1.33	5.00
Access[b]	47	3.69	.70	2.00	5.00	87	3.27	.66	1.80	4.60

Note. [a.] Mean difference between groups statistically significant at $p < .001$, [b.] Mean difference between groups statistically significant at $p = .001$

Implications for Practice

The findings from this study underscore the potential for systematic changes within undergraduate engineering programs to enhance the inclusion and sense of belonging among neurodiverse students. We suggest that the intentional infusion of strengths-based messaging throughout the engineering program, including in course materials, teaching methods, and faculty-student interactions plays a key role in cultivating an inclusive learning environment, and subsequently, a sense of belonging amongst neurodiverse engineering students [48]. This approach not only acknowledges but celebrates the unique perspectives and skills that neurodiverse students bring to the engineering discipline, fostering an environment where students feel valued and understood. Furthermore, this inclusive educational model, centered around appreciating cognitive diversity and promoting universal design for learning, holds promise for broader applications. It suggests a viable pathway for engineering programs to initiate cultural change, making the field more welcoming and accessible for a wide array of underrepresented or marginalized groups. By implementing such neuroinclusive practices, engineering programs can move towards becoming more equitable communities where diversity is viewed as an asset, contributing to a more innovative and inclusive future for the engineering profession. This strategic shift towards inclusivity not only benefits neurodiverse students but enriches the learning environment for all students, potentially leading to a more diverse, creative, and resilient engineering workforce.

Limitations of the Study

There are several limitations to this study. First, the relatively small sample size limits the generalizability of the findings. A larger sample size, as well as a study conducted across multiple institutions, could provide a more representative understanding of the ways in which inclusive pedagogies may foster a sense of belonging among engineering students. The survey design also does not provide longitudinal data that might reveal the long-term impacts of the implementation of neuroinclusive teaching practices in undergraduate engineering courses. This could overlook the potential cumulative effects of inclusivity efforts on student perceptions and experiences. The survey measures sense of belonging through self-report, which can be influenced by a range of factors including individual students' perceptions or mood. The next phase of the research will provide a way to triangulate this data to provide a more comprehensive understanding of the experiences of neurodiverse students in inclusive courses. Finally, the study does not delve into the intersectional nature of identity or the ways in which cultural and demographic factors, such as ethnicity, gender identity, and socio-economic status may influence students' sense of belonging in engineering

Future Research Directions

This research study examines predictors of belonging in engineering courses within the context of a departmental course redesign aimed at improving the learning experience for neurodiverse students by creating a more inclusive learning environment for *all* students. To learn more about the experiences of neurodiverse students, the second phase of the research, is a qualitative study investigating the experiences of students who self-identified as neurodiverse through the survey and also consented to participate in a follow-up interview about their experiences in their engineering courses. This qualitative exploration of neurodiverse students' experiences will provide in-depth data about the ways in which these students perceive and/or experience this departmental effort to increase inclusivity through systemic pedagogical and cultural changes.

Conclusion

In conclusion, the findings from the multiple regression model suggest that inclusion in the classroom is a significant positive predictor of students' feelings of belonging in engineering. This variable, along with engagement, instructional quality, learning development, and disengagement in the classroom, accounts for 18% of the variability in belonging. Additionally, when controlling for all other variables, inclusion in the classroom was the only significant predictor of belonging and had a moderate positive effect. Furthermore, the results of the independent samples t-tests indicate that students in neuroinclusive courses reported significantly greater inclusion compared to students in conventional courses. However, no significant differences were found between the two groups in terms of engagement, learning development, or disengagement. These findings suggest that inclusion in the classroom plays a crucial role in fostering a sense of belonging in engineering.

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