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Neurodivergent and Neurotypical Students in a First-Year Engineering Design Course: Identity, Self-Efficacy, and Experiences

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Abstract

This Complete Research paper explores the attitudes and experiences of neurodivergent (ND) and neurotypical (NT) students in the context of a first-year engineering design (FYED) course where students work in teams on open-ended projects. The data set includes post-survey data from Spring 2023 and pre- and post-survey data from Fall 2023. The end of the survey asked if students self-identified as neurodivergent (having one or more of the following: ADHD, ASD, dyslexia, etc.) with the response options of yes, maybe, or no. There were 63-67% of the students who self-identified as NT. On the Fall 2023 pre-survey, confidence in technical skills, confidence in non-technical skills, public/private regard for engineering, group identification with engineering, engineering self-efficacy, and engineering commitment were similar among ND and NT students. ND students had a higher centrality of engineering to their identity than NT students. The maybe ND students had lower group identification, engineering self-efficacy, and engineering commitment compared to the NT students. On the Spring 2023 post-survey, the NT students had somewhat more positive team experiences on average compared to ND and maybe ND students. Other course experiences and self-reported learning gains did not differ significantly between ND and NT students. On the Fall 2023 post-survey, the ND student responses were generally similar to those of their NT peers. In FYED courses with significant team-based work, extra attention to team formation and/or facilitation may be beneficial. Engineering faculty should consider both the assets and the challenges that neurodivergent students face.

Introduction

It is important that engineering attract and retain students from a variety of backgrounds in order to both meet the needs of society by filling job openings and provide diverse perspectives that improve engineered products and solutions. Further, providing equitable opportunities for students to pursue their interests and reach their goals is a matter of social justice. While engineering inclusion actions often focus on gender and race/ethnicity, increasing attention is beginning to be given to neurodiversity. This paper explores the attitudes and experiences of neurodivergent and neurotypical first-year engineering students in the context of a team-based design course. Student attitudes related to engineering identity, self-efficacy, and commitment were evaluated, comparing neurodivergent and neurotypical students.

Individuals possess a natural variety of traits that can impart advantages and disadvantages in particular contexts. Education has often taken a medical model approach [1], which labels some traits and conditions as deficits, and where individuals who are neurodivergent (ND) are perceived as abnormal and less competent than neurotypical (NT) students. Others use socio-ecological approaches and asset models when exploring differences [2-3]. This research used the framework of neurodiversity. Neurodiversity frames different neurological conditions of the brain and nervous system as providing affordances and posing challenges, encompassing both individual and social aspects [4].

Conditions that are traditionally defined as neurodivergent include attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), dyslexia, dyscalculia, dysgraphia, and trauma-related conditions such as traumatic brain injury [5-8]. A variety of mental conditions are also variously included under the umbrella of ND, including anxiety and depression [5]. Some research explores specific conditions, while other research has included ND students under the term 'non-visible disabilities' [9] The underdiagnosis of conditions like ADHD among females has been documented [10-11], so individuals may identify as ND without a formal medical diagnosis. Mirfin-Veitch et al. [6] state that "neurodiversity is not a diagnosis, rather it is a broad term used to encompass a wide range of specific, non-specific, hidden and/or undetermined diagnoses" (p. ii). The framing for this study aligns with this definition.

Neurodivergent students may differ from their NT peers in various capabilities. These differences may convey advantages in some settings [12-13]. For example, the hyperfocus on topics of interest among students with ADHD [14] can be leveraged to advantage if student interest in a topic can be generated. Other strengths of individuals with ADHD may include flexibility, sensitivity, cognitive dynamism, "many thoughts", energy, non-conformity, and better long-term episodic memory [14-17]. The cognitive and psychological skills of individuals with ASD and/or ADHD that are valued in cybersecurity [18] and information science [19] have been explored. These are just a few examples of assets that ND students can bring to their studies and have the potential to contribute to their work as engineers. Despite these strengths, ND students, such as those with ADHD, may have lower academic self-efficacy than their NT peers [20].

The ability to work in teams is important in engineering education and workplace settings [21-22]. Teamwork encompasses a variety of skills, which include interpersonal communication, organization, and conflict resolution [22-23]. Some ND conditions have been associated with difficulties in these areas (e.g., ASD with interpersonal communication [24]; ADHD with organization difficulties [25-26], self-perceived lower social skills [16], and antisocial disorders [27]). Zolyomi et al. [28] found that among teams with autistic and non-autistic students in higher education, the ND students "have difficulty expressing individual differences and addressing team conflict." Delp [29] discusses how teamwork is often a focus in first-year hands-on design courses and the likely impacts on students with ASD.

Previous research has explored the impacts of first-year engineering design (FYED) courses on the persistence, self-efficacy, and identity of engineering students; e.g., [30-31]. The active learning style typically used to teach first-year engineering design courses may be particularly well suited for students with ADHD. A study in physics found that "active learning environments… cater to ADHD students' strengths due to their flexibility and adaptability to unique ways of thinking and processing" [32].

Within engineering, previous studies have found that engineering identity contributes to persistence intentions and retention (e.g., [33]). Engineering identity is the extent to which a person feels like an engineer or their personal sense of themselves [34-35]. In this study, the framing of engineering identity includes the sub-elements of centrality, private and public regard, and group identification [36]. Centrality encompasses the extent that a student defines themself as an engineer. Private regard refers to the extent that a student individually holds positive

feelings toward engineering. Public regard is the extent a student believes others hold positive feelings about engineering. Group identification is the extent the student values being an engineer and feels a sense of belonging with other engineering students. A recent study by Hall [37] found that students who "met the screening criteria for [having] ADHD had significantly higher levels of identity distress and unproductive ruminative identity exploration." Occupational identity and self-identity impacts of ADHD were also found in adolescents [16],[38]. No published studies of engineering identity and ND were found.

Considering the differences previously documented among ND and NT students, this study considers whether students in a FYED course self-report different confidence in incoming skills, engineering identity, or learning outcomes from the FYED course.

Research Questions

RQ1: What percentage of students in a first-year engineering design course self-identify as neurodivergent (ND), maybe neurodivergent (mND), or not neurodivergent (therefore NT)?

RQ2: Do students who self-identify as ND or mND differ from NT students in their incoming confidence in technical and non-technical skills, engineering self-efficacy, engineering identity, or commitment to engineering?

RQ3: Do students who self-identify as ND or mND differ from NT students in their feelings of engineering identity, self-reported gains in technical and non-technical skills, team experiences, and commitment to engineering at the end of the semester in a FY design course?

RQ4: Are there differences in the extent to which engineering identity, engineering self-efficacy, and commitment to engineering changed across the semester among ND, mND, and NT students in a first-year engineering design course?

Methods

Context: This course explored students enrolled in a FYED course at the University of Colorado Boulder. The course is designed for all engineering majors in the College of Engineering, with the exception of chemical engineering; electrical and aerospace engineering also offer separate customized first-year design courses. Sections of the course typically enroll 30 students and are taught by instructors across the college. Course learning objectives include the engineering design process, engineering skills (e.g., CAD, circuits, manufacturing), teamwork, communication, and engineering ethics.

The course is coordinated by two individuals with extensive experience teaching first-year design courses. The course coordinators provide a syllabus, Canvas shell, example lectures, example homework assignments, and example grading rubrics. Instructors have the ability to use or modify these items, allowing them to use their own judgment on course activities that will achieve the five learning objectives for the course. For example, it is recommended that teams are formed based on social style information and do not isolate female students; but some instructors elect to form teams randomly or use other criteria. Similarly, instructors are

encouraged to give a peer evaluation survey that is used to gather feedback on individual contributions and interpersonal dynamics on the student teams; these are used to varying degrees. The multiple instructors are encouraged to meet together with the course coordinators in a supportive cohort for about 1 hour each week during the semester. Depending on schedule, experience level, and interest, instructor attendance at the weekly meetings varies. The instructional team also coordinates undergraduate course assistants across the multiple sections of the course.

In the FYED course, teams of four to six students complete one or two short introductory projects over the first 3 to 6 weeks of the course, followed by a more open project for the remainder of the semester. Instructors can select themes for the projects in their course (e.g., sustainability) or may provide specific requirements (e.g., all projects include circuits, Arduino, and a 3D printed part). Teamwork-related deliverables and activities are usually worth about half of the course grade. In Spring 2023 there were 11 sections of the FYED course taught by 8 different instructors; in Fall 2023 there were 12 sections of the course taught by 11 different instructors. Different majors recommend the course to their students in different semesters. For example, undeclared engineering majors are recommended to take the course in the Fall versus civil, architectural, and pre-engineering students in the Spring. (For information on pre-engineering see [39].)

Survey: The research was approved by an Institutional Review Board for Human Subjects Research (Protocol #11-0651). Pre- and post-survey instruments have been developed and iterated for a number of years [40-41]. Across all sections of the course, the same pre-survey is administered in the first week of the semester and the post-survey in the last week of the semester. Students are provided with the link to the survey in Qualtrics. The surveys begin with informed consent, and students 18 years of age or older can opt to participate in the research. Students also have the option of completing the survey for class evaluation purposes without consenting to participate in the research. Students provide their name and course instructor at the beginning of the surveys. Students can elect to skip any questions on the survey.

The pre-survey included items for students to self-rate their confidence on six technical skills (computer aided drafting, electronics, manufacturing, programming, prototyping (e.g., 3D printer), engineering analysis and product testing) and six professional skills (ethical reasoning, project management, public speaking, sustainable practices, teamwork, writing). The survey included items related to engineering identity (10 items; centrality, group identification, and public/private regard; [36]), self-efficacy in engineering (4 items), and commitment to engineering (3 items). The post-survey asked students to what extent they improved their skills in the six technical areas and six professional areas (matching the pre-survey items). The engineering identity, engineering self-efficacy, and engineering commitment items were repeated on the post-survey. The post-survey asked eight different questions about students' teamwork experiences in the course (see Appendix).

The surveys conclude with demographic items: gender with which they primarily identify (male, female, prefer to self-describe) and race/ethnicity descriptors (select all that apply). The final item on the survey asked students whether they self-identify as neurodivergent. The wording of

the item changed from the post-survey in May 2023 to the pre- and post-survey in Fall 2023 (bold text to highlight the differences):

> Spring 2023 post-survey: Do you self-identify as neurodiver**se** (having one or more of the following: ADHD, ASD, dyslexia, **brain injury**, etc.)?" Response options: yes, maybe / unsure, no.
>
> Fall 2023 post-survey: Do you self-identify as neurodiver**gent** (**based on brain function and/or traits such as** ADHD, **anxiety,** ASD, dyslexia, **PTSD**, etc.)? Response options: yes, maybe / unsure, no.

Analysis: The survey data were exported from Qualtrics. Responses indicating that they did not consent to participate in the research were deleted. It was found that a few individuals responded more than once. The most complete response was retained. If the level of completion matched, the earlier response was retained. For the post-survey in Fall 2023, it was also found that some individuals did not complete the entire survey, and thus some demographic information was missing. For students who had consented on the pre-survey and provided their demographic information, this was used to fill in missing data from the Fall 2023 post-survey for 10 individuals.

Note that there was a much higher participation rate, which included answering the ND question, on the Fall 2023 pre-survey (91%) compared to the Spring 2023 post-survey (61%) and Fall 2023 post-survey (78%). Among the post-survey respondents in Spring 2023, the gender identification was 28.6% female, 69.3% male, 1.1% other, and 1.1% blank or prefer not to say. The most common engineering majors among the Spring 2023 respondents were mechanical (n=55), pre-engineering (n=44), aerospace (n=25), environmental (n=20), and civil (n=14). Among Fall 2023 pre-survey respondents, the most common majors were mechanical (n=118), undeclared engineering (n=79), aerospace (n=68), and environmental (n=31). The most common student majors on the Fall 2023 post-survey were mechanical (n=97), aerospace (n=53), environmental (n=25), and undeclared engineering (n=24).

Analyses of statistical differences among ND and NT students were conducted using Mann Whitney U tests, a non-parametric statistical test between two sets of data, looking at p values from the two-tailed tests. For p values below 0.05 differences between the groups were inferred (only a 5% chance of a Type I error and incorrectly rejecting the null hypothesis); p values 0.05 to 0.10 were suggestive of likely differences (up to a 10% chance of a Type I error) and are also shown [42]. For the paired pre-post data from Fall 2023 a paired t-test was used, along with a Wilcoxon signed-rank test (the non-parametric equivalent of a paired t-test) when the sample size was less than 200. The effect size was also computed to inform issues related to Type II errors or incorrectly concluding a lack of difference between the compared groups [42]. Cohen's d was manually calculated in the paired tests by dividing the mean difference by the standard deviation [43]. The rules of thumb are that Cohen's d values of 0.2-0.5, 0.5-0.8, and above 0.8 represent small, medium, and large effect sizes, respectively [44].

Limitations: Students self-reported ND, which encompasses a broad range of conditions. The literature itself differs in the conditions that are classified as neurodiverse. In addition, formal

diagnosis varies among different demographic groups (e.g., [10]), with particular concerns that females are underdiagnosed ([11]). Combining all different types of ND together into a single category may cause the research to fail to identify assets or challenges faced by students with particular conditions (e.g., ASD differs from ADHD). Students may also elect not to report their ND given the potential for social stigma [45-46]. In addition, students' survey responses may not be fully accurate but may be subject to bias by social desirability, positive response, and other response patterns; e.g., [47]. The ability of these simplistic Likert-type items to accurately reflect the complexity of student identity and self-efficacy is suspect. Intersectional demographics were not explored (e.g., gender, race/ethnicity, ND/NT, first-generation, low income, etc.). Participation rates among the students enrolled in the class were high, so nonresponse bias [48] is presumed to be minimal.

Limitations in the study may also stem from the FYED course. Given the wide variety of instructors, the specifics of individual course sections vary [49]. This includes how teams are formed, facilitating team issues, and individual assignments. The majors of the students in the FYED differed between the Spring and the Fall terms, with about about half of the Spring students in a pre-engineering major trying to earn entry into the College. In Fall 2023, the vast majority of FY engineering students were living in a supportive residential academic program together; this was not the case in Spring 2023. The broader first-year experience (beyond the FYED course itself) could impact students' engineering identity, self-efficacy, and commitment.

Results and Discussion

RQ1. Prevalence of ND

The student answers to the ND question at the end of the survey are summarized in Table 1. The survey results reveal that 14% to 18% of the students self-identified as ND, with an additional 17% to 22% indicating that they were maybe ND. The confusion likely stems from a combination of the conditions that count as ND, as well as students who may lack a formal diagnosis. Interestingly, the Fall 2023 pre-survey had a higher percentage of female students who indicated they were maybe ND (27%), compared to the post-survey (18%). Fewer students responded to the post-survey, so perhaps a number of the maybe ND female students simply did not take the post-survey.

Table 1. Percentage of students identifying as ND among all students and among male and female students.

Response	Post Spring 2023			Pre Fall 2023			Post Fall 2023		
	% All (n=189)	% M (n=130)	% F (n=52)	% All (n=335)	% M (n=217)	% F (n=118)	% All (n=270)	% M (n=176)	% F (n=87)
Yes ND	18	19	15	14	12	19	15	14	18
Maybe ND	19	18	20	22	19	27	17	16	18
No (NT)	63	63	65	64	69	53	67	69	64

^ *Some students self-identified their gender, including transfem nonbinary, non-binary*

Among paired individuals between the pre- and post-survey in Fall 2023, students selected the same ND response in only 79% of the cases (the same response for 196 of 249). The highest agreement was among those who indicated they were not ND (therefore NT) in the pre-survey (89% also NT on the post-survey). The lowest agreement was among students who indicated

they were maybe ND on the pre-survey (only 50% also answered maybe ND on the post-survey). The low consistency among the mND students has a number of potential causes. A student who suspected a condition on the pre-survey may have been formally diagnosed one way or another by the post-survey. Or perhaps they were unfamiliar with the concept of neurodiversity at the start of the semester but gained understanding during the semester, which enabled them to more confidently categorize themselves. Further, aligned with the neurodiversity framework, individuals may choose to self-identify or not, and this identification may vary for different purposes [50]. For RQ4, which relates to paired data, only the students whose ND/mND/NT answers matched on both the pre- and post-survey in 2023 are included.

The percentages of ND students are in the range of literature values. In a recent study by Hall [37] an ADHD screening tool identified close to 50% of the college students as possibly having ADHD. Among first-year college students in 2022 there were 13.2% with ADHD (14.9% male, 12.3% female), 2.1% with ASD (2.5% male, 1.3% female), 5.5% with a learning disability (e.g., dyslexia; 5.1% male, 5.9% female) [51]; these conditions may co-occur in the same student [25],[52]. It has also been reported that a higher percentage of ASD students elect STEM majors in college [53]. The percentage of ND engineering students is likely higher than most faculty would expect. Given the range of potential conditions that are included under the title of neurodivergent, instructors cannot assume that particular teaching styles will be more effective than others. Rather, the approach of Universal Design for Learning (UDL) may be best suited to supporting ND students [54].

RQ2. Incoming Attitudes

The Fall 2023 pre-survey results were explored to identify potential differences in the attitudes of the entering students who identified as ND or NT. On the pre-survey, the majority of the construct scores were not significantly different between ND and NT students. The only exception was the higher engineering identity facet of centrality among the ND students compared to the NT students. A representative survey item for centrality with the largest difference in the average extent of agreement between the ND and NT students was “In general, being an engineering student is an important part of my current self-image.”

Table 2. Average and standard deviation of student ratings on the pre-survey.

Construct	N Items	Scale	ND (n=47)	Maybe ND (n=74)	NT (n=214)
Technical skills (prepared)	6	1 to 5	2.40 ± 0.83	2.32 ± 0.91	2.41 ± 0.85
Professional skills (prepared)	6	1 to 5	3.48 ± 0.55	3.38 ± 0.76	3.49 ± 0.66
Identity: centrality	3	1 to 7	5.24 ± 1.10**	4.80 ± 0.97	4.99 ± 1.28
Identity: public/private regard	3	1 to 7	6.08 ± 0.56	5.96 ± 0.63	6.09 ± 0.64
Identity: group identification	4	1 to 7	5.62 ± 0.79	5.44 ± 0.80 *	5.76 ± 0.83
Engineering Self-Efficacy	4	1 to 7	5.68 ± 0.73	5.56 ± 0.71 *	5.85 ± 0.69
Engineering Commitment	3	1 to 7	5.74 ± 0.61	5.36 ± 0.73 *	5.58 ± 0.73

Compared to NT, Mann-Whitney test * $p<0.05$, ** $p<0.001$

The students who self-characterized as maybe ND compared to the NT students had lower group identification (e.g., “I see myself as an important part of engineering students on campus”), engineering self-efficacy (e.g., “I will be able to achieve most of the engineering-related goals

that I have set for myself"), and engineering commitment (e.g., "I have no doubt that I will graduate with a degree in engineering"). Students uncertain about their ND status may be more generally uncertain.

The similarity among the self-rated confidence in their technical and professional skills among the students irrespective of neurodivergence is worth noting. This contrasts with studies that have found lower self-efficacy in adults and students with ADHD [55-57]. When asked about prior engineering exposure before enrolling in college, the average was lowest among ND students (average 2.29 between '2 = a little' and '3=some') but not significantly different than maybe ND students (average 2.42) and NT students (average 2.51). Thus, instructors can not assume that ND students are less prepared or confident in their engineering skills compared to NT students, but can provide additional accommodations upon request.

RQ3. End-of-course results

The results from the survey at the end of the semester are summarized in Table 3. The results generally show strong similarities in student responses regardless of being neurodivergent or neurotypical.

Table 3. End-of-Semester average and standard deviation among students grouped by ND.

Construct (N items)	**Spring 2023**			**Fall 2023**		
	ND (n=33)	**Maybe ND** (n=36)	**NT** (n=117)	**ND** (n=40-41)	**Maybe ND** (n=46-47)	**NT** (n=175-182)
Teamwork (8)	5.02 ±1.01	5.08 ±0.82	5.26 ±0.78^{+}	5.21 ±0.56	5.09 ±0.75	5.15 ±0.70
Technical skill growth (6)	3.29 ±0.78	3.37 ±0.76	3.34 ±0.75	3.49 ±0.63	3.37 ±0.75	3.45 ±0.74
Professional skill growth (6)	3.02 ±0.76	3.29 ±0.56	3.20 ±0.72	3.39 ±0.57	3.21 ±0.73	3.34 ±0.75
Identity: centrality (3)	5.13 ±1.02$^{\wedge}$	5.55 ±1.25$^{\wedge}$	5.16 ±1.25$^{\wedge}$	5.58 ±0.80	4.72 ±1.49*	5.29 ±1.35
Identity: public / private regard (3)	6.22 ±0.72	5.97 ±0.78	6.09 ±0.65	6.04 ±0.64	5.92 ±0.76	5.99 ±0.74
Identity: group identification (4)	5.88 ±0.79	5.63 ±1.24	5.68 ±0.86	5.57 ±0.91	5.34 ±1.22*	5.76 ±0.81
Engrg Self Efficacy (4)	5.68 ±1.24	5.85 ±0.90	5.67 ±0.95	5.56 ±0.88	5.38 ±0.97	5.57 ±0.85
Engineering Commitment (2)	5.11 ±0.85	5.19 ±0.93	5.12 ±0.93	5.54 ±0.63	4.85 ±1.11*	5.34 ±0.80

Mann Whitney U test vs. NT, * $p<0.05$

Mann Whitney U test NT vs. yes/maybe $^{+}$ $p < 0.10$

^ these items were not asked for pre-engineering majors in Spring 2023 so n=20 ND, 28 maybe ND, and 94 NT

Students self-rated the extent that their technical and professional skills increased during the semester. The average was between somewhat improved (3) and very improved (4), and did not differ significantly between ND, maybe ND, and NT students.

Among the Fall 2023 results at the end of their first semester of college, the students who self-identified as maybe ND had lower engineering commitment, centrality of engineering to their identity, and group identification as part of their engineering identity. This may have been due to struggling in their first semester courses (perhaps calculus, physics, and/or chemistry) which deterred them from engineering and/or they discovered other interests. Students with undiagnosed ND would not receive accommodations, and therefore these students may be struggling more than ND students with accommodations or NT students. Further research would be needed to verify or refute these potential reasons behind the numbers. It is also noteworthy

that the dispersion (standard deviation) among the maybe ND students' group identification and engineering commitment were also higher than the ND and NT students. The pre-survey at the start of the semester also found lower engineering commitment and group identification among the maybe ND students.

Looking at the intersection of gender with ND in the Fall 2023 data, the only statistically significant differences were the extent to which students perceived that they had improved their professional skills, which was higher among female vs. male ND students (3.6 vs. 3.2, p 0.013). There was a higher centrality of engineering identity among female vs. male NT students (5.5 vs. 5.1, p 0.050). Previous identity studies in the literature have reported no difference in identity between female and male students [36] or a lower identity among female students [58]. There were also differences among male ND vs. male NT students in the centrality of engineering identity (5.6 vs. 5.1, p 0.04) and engineering commitment (5.7 vs. 5.3, p 0.002).

Among the Spring 2023 end-of-semester results, there was a potential difference in the teamwork ratings among ND plus maybe ND students (average 5.05) versus NT students (average 5.26; p 0.07). The largest difference was in the item "I felt comfortable on my project team." This less optimal team experience among ND students is not unexpected given previous studies about team issues among students with ADHD and ASD [25-29]. If students rated their experience on their project team at a 3 (somewhat negative) or lower (7-point scale), the survey asked them to "please explain what was negative about the experience." There were not many write-in responses, but the types of elements (uneven work contribution, personality conflicts) did not show obvious differences among ND, maybe ND, and NT students. Example quotes below:

> "My group was difficult to count on. A lot of times they just wouldn't show up when they said they would, and they would not 'pull their weight'. Me and one other teammate ended up doing the lions share of stuff." Male ND student
>
> "Didn't get along with some group members." Male ND student
>
> "Bad group organization." Female NT student
>
> "Honestly my group didn't work well when it came to personality wise." Female NT student

On the Spring 2023 survey, there were not statistically significant differences between ND or maybe ND and NT students for attributes related to engineering identity, engineering self-efficacy, engineering commitment, or gains in professional or technical skills. It is considered a positive that ND students did not differ significantly from their NT peers on these items. In Spring 2023, there were a smaller number of responses to compare in the groups versus Fall 2023, but the mean values also differed less among the groups.

In the Spring semester, the majority of the students were in their second semester of college. Students who found other interests or may have been struggling likely would not enroll in the FYED course, which is specific to engineering. In addition, the Spring course enrolled a number of students who were actively trying to get into the College of Engineering. These students were likely confident of success, thereby choosing to take the FYED course that would only be required in their major if they successfully matriculated into engineering based on their technical GPA. Students who were ND or maybe ND likely developed success strategies in courses and may have integrated into supportive groups with other students that boosted their identity and sense of belonging. In addition, students who suspected they were ND may have sought

treatment and/or accommodations that were meaningful in bolstering the quality of their college experience.

RQ4. Paired pre/post results

Across all 241 students with both pre- and post-survey responses, paired statistical tests were conducted across the multi-item identity, self-efficacy, and commitment constructs; the results are summarized in Table 4 (values in bold are typically considered statistically significant). The pre- and post- ratings for all of these attributes were moderately correlated. Centrality, engineering self-efficacy, and engineering commitment differed between the pre- and post-survey. On average there was an increase in centrality (+0.18), a decrease in engineering self-efficacy (-0.23), and an increase in engineering commitment (+0.50).

Looking at sub-groups and only students who reported the same response to the neurodivergent question, the NT student results mirror the overall student findings (logical because NT is the largest fraction of the paired students), with increased centrality, decreased engineering self-efficacy, and increased engineering commitment. Among the ND students, the only significant difference was between pre and post engineering commitment, which increased on average. Among the maybe ND students, the only significant difference was in engineering commitment which increased on average; there were suggestive differences between public/private regard (which decreased) and engineering self-efficacy (which decreased).

Table 4. Results of paired tests between pre and post survey responses.

Group Parameter	Identity: centrality	Identity: public / private regard	Identity: group identification	Engineering Self-Efficacy	Engineering commitment
All (n=241)					
% students increased	46.9	32.8	40.2	31.5	71.8
% students no change	17.0	26.1	17.8	20.3	10.0
% students decreased	36.1	41.1	41.9	48.1	18.3
Change Avg ± stdev	0.18 ± 1.34	-0.07 ± 0.67	-0.03 ± 0.87	-0.23 ± 0.88	0.50 ± 0.81
Pair t-test, p	**0.007**	**0.096**	0.603	**6.0E-05**	**1.4E-18**
Cohen's D	0.13	0.10	0.03	**0.26**	**0.62**
Correlation	0.494	0.532	0.498	0.392	0.493
ND avg (n=22)					
Change Avg ± stdev	0.03 ± 1.00	0.02 ± 0.57	0.03 ± 0.70	-0.18 ± 0.88	0.63 ± 0.67
pair t-test, p	0.889	0.902	0.823	0.344	**0.00025**
Cohen's D	0.03	0.04	0.04	0.20	**0.94**
Correlation	0.397	0.625	0.644	0.497	0.467
mND (n=26)					
Change Avg ± stdev	-0.04 ± 1.34	-0.19 ± 0.51	0.00 ± 1.04	-0.39 ± 0.98	0.40 ± 0.73
pair t-test, p	0.885	**0.0656**	1	**0.051**	**0.010**
Cohen's D	0.03	**0.37**	0	**0.40**	**0.55**
Correlation	0.274	0.689	0.374	0.412	0.640
NT (n=140)					
Change Avg ± stdev	0.32 ± 1.32	-0.08 ± 0.73	-0.01 ± 0.84	-0.27 ± 0.89	0.51 ± 0.77
pair t-test, p	**0.001**	0.220	0.900	**0.0004**	**7.5E-13**
Cohen's D	**0.24**	0.10	0.01	**0.31**	**0.67**
Correlation	0.493	0.465	0.443	0.358	0.488

Bold indicates $p < 0.10$ or Cohen's D >0.2 (> small effect size)

Summary and Conclusions

About one-third of the first-year engineering students identified as neurodivergent or maybe neurodivergent (14-18% ND, 17-22% maybe ND, and 63-67% NT). A number of different conditions are grouped under the generic label of neurodivergence. Neurodivergent students will variously possess assets and challenges in their engineering journeys.

On the pre-survey, there were few statistically significant differences that were found between ND and NT students. Across survey items related to incoming confidence in technical and non-technical skills, there were not significant differences among ND, mND, and NT students. Among the incoming FY students, the centrality facet of engineering identity was higher among ND students than NT students; public/private regards and group identification were not significantly different. Engineering group identification, engineering self-efficacy, and engineering commitment were lower among the mND students compared to the NT students.

In the post-survey at the end of the semester, there were very few differences between ND and NT students. Among first-semester students in Fall 2023, ND and NT students did not differ significantly in teamwork experiences, technical or professional skill growth, three facets of engineering identity, engineering self-efficacy or engineering commitment. The maybe ND students had a lower centrality of engineering identity, group identification, and engineering than the NT students. Among the Spring 2023 post-survey respondents, the only difference was a lower satisfaction with teamwork among the ND plus maybe ND students compared to the NT students.

Among students who completed both the pre- and post-survey in Fall 2023, on average individuals increased in the centrality of engineering to their identity, increased in their commitment to engineering, and decreased in their engineering self-efficacy. The increase in identity centrality was only found among NT students. The increase in commitment to engineering occurred in ND, mND, and NT students. The decrease in engineering self-efficacy was only statistically significant among mND and NT students (on average there was also a small decrease among ND students, but the change was not statistically significant).

It is important to recognize that engineering identity, self-efficacy, and commitment are influenced by the sum of an individual's experiences. Therefore, the changes across the semester should not be solely attributed to the first-year engineering design course. For example, decreases in engineering self-efficacy might be due to struggles in math or natural science courses rather than their experience in the FYED course. The similarity in student perceptions of their gains in technical and professional skills regardless of being NT or ND is encouraging and perhaps attributable to the hands-on, open-ended nature of the instruction.

It is important that engineering faculty and students consider both the assets and the challenges that neurodivergent students face. In FYED courses with significant team-based work, extra attention to team formation and/or facilitation may be beneficial. It is interesting that the results in Fall semester (similar teamwork experience ratings between ND and NT students) differed from Spring semester (less favorable teamwork experience ratings by ND+mND students compared to NT students). Instructors differ between semesters, among other factors that

complicate comparisons between semesters. Attention to bolstering engineering identity and self-confidence among all students is important. FYED course instructors should consider that students may be facing challenges in other courses (e.g., calculus), which may be eroding their self-confidence. FYED courses can be sites where ND students gain confidence in their ability to succeed in engineering.

Future Work

The results point to a number of interesting questions for further research. Both quantitative and qualitative studies are likely to yield useful insights. Students who self-identify as ND or maybe ND on the survey could be asked to elaborate on their response. This could include whether they are under treatment, have received academic accommodations, and/or their type of neurodivergence. However, these questions might be perceived as invasive, so the survey should clearly indicate that responses to these questions are optional. Perhaps even provide separate consent specific to this information.

Within the course, students complete peer assessments. It would be interesting to explore how ND and NT students perceive their teammates and whether there are differences among ND and NT students and/or specific types of neurodivergence (such as ASD). It is possible, for example, that ND students might be unaware that their peers are frustrated with them. Interviews with students could support these peer ratings.

It is also worth studying intersectional characteristics and multiple non-normativity; students who identify with multiple characteristics that are non-normative in engineering (e.g., female, minoritized race/ethnicity, ND) may have different attitudes and experiences. More broadly beyond the FYED course, a longitudinal study could track engineering students' confidence in their traits and abilities beyond a single semester. Differences across the entirety of the first-year experience could provide insights. This might be combined with information on courses and student grades to provide a more complete picture.

The extent that students self-identify as ND could be shared in the FYED course as a means to normalize these differences. Discussion of diagnosis and accommodations might encourage students who are uncertain whether or not they are neurodivergent (the maybe ND students) to seek out resources to gain clarity. College is a time of growing self-awareness, so this aligns with other individualization and self-advocacy processes. A brief reflective assignment that asks all students to consider personal assets and challenges that they are facing in their collegiate journeys might be beneficial. The FYED course already introduces students to social styles, and this information is often used in teaming. The instructional team could consider whether this exercise could be modified to introduce other diversity characteristics and specifically address neurodivergence and potentially mental health issues. The faculty development series for instructors could also introduce topics related to ND and encourage faculty to integrate UDL principles.

Appendix

Survey items to measure **teamwork** experiences during the semester (response options):

- Rate your experience on your project team this semester (strongly negative – strongly positive)
- I felt comfortable on my project team (strongly disagree – strongly agree)
- I feel that I am a part of my project team (strongly disagree – strongly agree)
- I feel that I am supported on my project team (strongly disagree – strongly agree)
- I feel that I am accepted on my project team (strongly disagree – strongly agree)
- Extent that you improved your teamwork skills this semester (not at all – extremely improved)
- The focus on team growth was helpful to my learning (strongly disagree – strongly agree)
- How did the focus on team growth throughout the semester contribute to your sense of belonging in our engineering community? (not at all – extremely)

Post survey items to measure **engineering self-efficacy** (response options strongly disagree – strongly agree):

- I will be able to achieve most of the engineering-related goals that I have set for myself
- When facing difficult tasks within engineering, I am certain that I will accomplish them
- I believe I can succeed at most any engineering-related endeavor to which I set my mind
- I am confident that I can perform effectively on many engineering-related tasks

Post survey items to measure **commitment to engineering** (response options):

- I have no doubt that I will graduate with a degree in engineering (strongly disagree – strongly agree)
- It is my intention to pursue a career in engineering (strongly disagree – strongly agree)
- Do you intend to complete a major in engineering? (definitely not – definitely yes)

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