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Work-In-Progress: Exploring the Contributions of Varied Neurotypes to Innovation in Engineering Teams through Qualitative Analysis of Reflective Memos

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Abstract

Different neurotypes enhance engineering by bringing varied cognitive perspectives and problem-solving approaches that foster creativity and innovation. Neurodivergent individuals, including those with autism, ADHD, and dyslexia, often excel in skills like pattern recognition, systems thinking, and attention to detail, which are vital in engineering. This study examines the role of neurotypes in team-based projects within a junior-level environmental engineering course supported by NSF Award #2205067. Over 10 weeks, student teams (3–5 members) designed K-12 learning activities integrating water chemistry concepts, guided by a K-12 teacher and an engineering mentor. To build innovation self-efficacy, students completed three team-based reflective memos and two individual memos. This paper compares two teams: one with mixed neurotypes (ND) and one neurotypical (NT). The ND team included students with diagnoses such as PTSD, anxiety, autism, and ADHD, as well as neurotypical students, while the NT team consisted entirely of neurotypical students. Reflective memos were analyzed using Constant Comparison Analysis (CCA) and scored for depth of learning using Moon's Map of Learning. Results showed the ND team achieved higher overall depth scores (37.7) across five memos compared to the NT team (29.5). While the ND team members scored lower in individual reflective memos on average (11.4 vs. 15.4), their team-based submission scores were 54% higher than the NT team's. These findings highlight the value of varied neurotype perspectives in enhancing the depth of learning and innovative thinking in team-based engineering projects. The unique strengths of neurodivergent individuals appeared to contribute to richer, more creative outcomes in the team setting, emphasizing the importance of embracing neurotypes in engineering education.

Keywords: Neurodivergent, neurotypes, innovation, team-based learning, reflective memos.

Introduction

Innovation is an important skill in engineering. The world needs new products and processes to solve complex challenges related to sustainability, resilience, and meeting needs for a thriving economy and society. The *Engineering Mindset Report* highlights the need to redefine engineering as "the process of problem-solving and innovation using tools such as mathematics and the basic sciences, along with many other skills" [1, p. 41]. There are many different models for innovation. This study used the model from Dyer et al. [2], which considers five types of innovative behaviors (questioning, observing, networking, experimenting, and associational thinking) that lead to the cognitive skill of associational thinking, which in turn leads to innovative business ideas.

Previous studies have found benefits when teams include individuals from different backgrounds. These studies have explored various aspects such as gender [4], race/ethnicity [5], and age/experience [6]. The 2024 Inclusive Engineering Mindset report noted, "innovation... stems from diverse ways of knowing" [1, p. 14]. However, few studies have explored neurodiversity, particularly how the unique cognitive strengths and perspectives of neurodivergent individuals contribute to engineering innovation and problem-solving, leaving a critical gap in understanding and leveraging this aspect within STEM fields.

There is increasing awareness of the variety of neurotypes that exist. Conditions typically characterized as neurodivergent (ND) include autism, ADHD, dyslexia, dyspraxia, dyscalculia, Tourette syndrome, and other cognitive or neurological differences that impact learning, communication, and social interaction. Recognizing and valuing these diverse ways of thinking can foster more inclusive and innovative environments in engineering education and practice. An asset-based framing of neurodiversity recognizes that these conditions are not deficits but instead represent unique strengths and perspectives that can drive creativity, innovation, and problem-solving. By embracing the inherent value neurodivergent individuals bring - such as pattern recognition, hyperfocus, creativity, and unconventional problem-solving - engineering education and practice can become more inclusive while unlocking new opportunities for innovation and progress [7-8]. In a study that paired autistic and non-autistic adults, their spaghetti towers exhibited the least similarity compared to towers constructed by pairs of adults with the same neurotype [9]. This study explored a type of creativity that might be relevant in engineering, highlighting the potential for teams of mixed neurotypes to generate innovative and unconventional solutions by integrating distinct cognitive approaches and perspectives. Such findings underscore the importance of fostering neurodiversity in collaborative engineering environments to enhance problem-solving and design outcomes.

Research Question

To explore how neurotype perspectives influence collaborative engineering tasks, this exploratory study examines the following research question:

- In what ways do engineering teams that include students with diverse neurotypes demonstrate innovative behaviors and cognition in reflective memos compared to teams without neurodiversity?

Methods

This research was conducted within the context of a larger study funded by the National Science Foundation (Award #205067). The research was approved by the institutional review board for human subject research at the University of Colorado Boulder (Protocol #23-0388). The study focused on Junior to Senior level students enrolled in a fall 2023 Water Chemistry course. The course is required for students majoring in Environmental Engineering. At the beginning and end of the semester, students were invited to participate in the research study and given surveys where they identified their gender identity, race, and whether or not they identified as neurodivergent (ND). If the students answered either Yes or Maybe ND, they were given the option to list which type(s) of ND they identified with. Within the course, 41 students participated in the pre and/or post-survey (91% responded; only 35 completed both surveys). Only the 7 teams where every participant consented to participate were examined in the research (out of a total of 11 teams).

A key activity in the course designed to foster innovation skills was a 10-week long open-ended, team-based project to design an activity for K-12 students to illustrate a concept from water chemistry. Details of the project have been published; see [10]. At the beginning of the semester, students were randomly grouped into teams of 4-5 (in one case a student dropped the course resulting in a team of 3 students). Teams and/or individuals were assigned to write short Reflective Memos (RMs) throughout the semester in order to scaffold their learning through types of innovative behaviors and cognitive skills (under Dyer's innovator's model [2-3]). As depicted in Table 1 below, two RMs were given as individual assignments (RM2 Observing and RM4 Networking), and three were assigned to be completed as a team (RM1 Questioning, RM3 Experimenting, RM5 Associational Thinking).

Table 1- Reflective Memo (RM) prompts; responses were limited to 100-200 words.

Reflective Memos
RM1- Group submission. What questions came to your mind while designing your activity and how did you think about them? Some examples of basic questions to ask are questions about your audience, material, space, scope of work, etc. How can you ask questions that are creative and nontraditional?
RM2- Individual submission. For the activity that you are designing, in what ways did you study or observe the world to generate new ideas? Some examples include studying how natural waters connect, reflecting on your own experience, watching how young adults learn, the extent of global environmental pollution, etc.
RM3- Group submission. For the activity you are designing, to what extent and how did experimenting assist you in searching for new ideas or creating your design?
RM4- Individual submission. Concept maps can be useful in conveying concepts, ideas, and pieces of information visually and can help us understand the relationships between various ideas and organize our findings logically and visually. For the activity that you are designing, draw your concept maps (idea network), and mention those whom you interacted with to generate ideas (i.e., peers, other faculty, parents).
RM5- Group submission. For the activity you are designing, which different or diverse areas does your designed activity connect? Feel free to be creative. Some examples include cooking, astronomy, art, sports, music, medicine, etc.

After the semester ended, the research team, made up of three undergraduate students and two faculty members, worked to create sub-categories of themes for each RM based on trends that were identified across answers for each individual RM. These sub-categories were then cross-compared to establish six overarching categories for consistency across the different RMs. Individual RMs contained 3 to 5 categories, with each category including 1 to 3 sub-categories. The synthesis of these categories and sub-categories across the 5 RMs is summarized in Table 2.

Reflective memos were analyzed using Constant Comparison Analysis (CCA) and scored for depth of learning using Moon's Map of Learning [11]. This learning map has 5 levels corresponding to surface learning at level 1 (noticing) up to deeper learning at level 5 (transformative learning). Each sub-category was scored on a scale of 1 to 5. For categories with sub-categories, the individual sub-category scores were averaged to create a single score to simplify the analysis in this paper. Three undergraduate students rated each RM independently and then met to negotiate consensus scores.

Table 2- Categories and sub-categories across the 5 RMs. Each column represents one of the 5 RMs, and each row represents one of the six categories (displayed in Figure 1 in the same order).

Category	Description	Sub-categories				
		RM1 Questioning	**RM2 Observing**	**RM3 Experimenting**	**RM4 Networking**	**RM5 Associational Thinking**
World view / outside connections	Second or third hand	none	Making connections	Purpose oriented experimentation	World view integration	Drawing conclusions Articulation of real world Project briefing
Project limitations	Various limitations	Project limitation	none	In-class time Conducting feasibility study	Trial & error in design	none
Curriculum / water chemistry topics	Connect to something being learned in-class or at university related to WC	Reflection of curriculum	Leveraging	none	none	Cross disciplinary Sensible integration
Personal world view connections	First-hand experiences outside of school	Personal reflection	Prior educational Anecdotal evidence	none	Real world manifestations	none
Stakeholder – centered design	Considered K12 teachers or students	Audience consideration Impact	Audience consideration	Audience	Audience	Project objectives
Mentors	Mentioned mentors	none	none	Mentor influence attribution	Mentor influence attribution	none

	Color Code	Definition/Meaning
1	World View/ Outside Connections	Second or third hand
2	Project Limitations	What limitations have the students found when looking at the project, works with stakeholder-centered design to some extent, however more specific to any possible limitations rather than ones that may effect the stakeholders
3	Curriculum/Water Chemistry topics	Students connect project to something they are currently learning or have learned during their time in university, generally more geered towards water chemistry topics
4	Personal World View Connections	First hand experiences outside of school
5	Stakeholder - Centered Design	Students consider different aspects of their design from the perspective of a stakeholder, or in other words the teachers and students
6	Mentors Mentioned	Were Mentors mentioned/ used for this RM

Figure 1. Category chart showing each of the 6 categories and the definitions of what should be considered to fulfill the category.

There were 7 teams where all students consented to participate in the research. For this work-in-progress, the research team elected to compare the team that included the most and least amount of neurotypes. Teams were ordered from the least to the most number of ND individuals based on their pre-survey identification. The team with the most ND was Team F with 2 Yes, 1 Maybe, and 1 No (NT). The write-in responses identified the types of ND as autism, ADHD, PTSD, and anxiety. The students on this team varied in gender, comprising 2 females, 1 male, and 1 non-binary individual, and in race/ethnicity, with 3 white students and 1 Hispanic student. The team with the least ND was Team D, with all 4 students not ND (all NT). However, the team did have a mix of genders, with 1 female and 3 males, and race/ethnicity, including 3 white students and 1 Asian student. The other 5 teams included one to two students who self-identified as yes or maybe neurodivergent; these teams are not analyzed in this paper.

RM individual scores were analyzed. It was found that no singular individual was consistent in performing in a specific way that might produce a skewed effect on group scores. Therefore, the individual scores were averaged to create singular group scores for RM2 and RM4, which allowed comparison across all five RMs. In some cases, individual students did not complete an RM. Categories that did not appear on a memo were not assigned a score and were left blank to properly represent their lack of influence on the overall totals.

Limitations

The primary limitation is due to comparing only two groups. Differences between the groups might be due to factors other than the variety in neurotypes among the team members. There was some level of subjectivity among the scoring. The reflective memos were short, which limited the amount of information available (see Table 3). Teams may not have taken the same level of care when completing the memos, and therefore, they are inaccurate reflections of the true thought processes of the team. Individual students on each team performed differently on the individual reflective memos, and the averaging approach used may not be optimal (particularly in cases where 1 team member did not submit the memo, so the average does not represent all 4 of the students on the team). It is unclear to what extent, in a team setting, a high-performing student might dominate the team rather than an "averaging" of performance occurring. Word counts in reflective memos are depicted in Table 3 (RM2 and RM4 were individual; RM4 was a concept map so the number of nodes was shown; a range of individual counts shown).

Table 3 – Word count of Reflective Memos (RMs), i denotes individual-based submissions, and i^ concept maps submitted individually (numbers represents the number of nodes).

Team info & Neurotype	**RM1**	**RM2i**	**RM3**	**RM4i^**	**RM5**
Team F - ND	185	120 - 182	97	7 - 16	103
Team D - NT	217	104 - 145	105	11 - 14	129

Results

Table 2 displays the normalized RM scores in each category for groups F and D. These category scores can range from 0 (no evidence in the RM) to 5 (evidence of transformative learning). Green shading has been added to highlight higher scores. Below the charts, the total scores for each RM are provided. Across the three group-based reflective memos, Team D had a total score of 14.2 compared to the total score of 26.3; thus, there was evidence of deeper learning across more categories for the team with more variety in neurotypes among the students. In contrast, the sum of the average of the two individual RM scores was 15.4 for Team D (NT) and 11.4 for Team F (ND). This appears to show synergy among the members of the ND team, with higher team RM scores (11.5, 7.5, 7.3) than average individual RM scores (5.7, 5.7). In contrast, the team RM scores (5.5, 4.0, 4.7) are lower than the average individual scores (7.4, 8.0) on the team where all members were neurotypical. It is important to note that individual scores on both teams varied significantly which prevents simple comparisons. However, there is no evidence that Team F (ND) had individually stronger students which drove their team RM performance stronger compared to Team D (NT).

*Table 4. Comparison of reflective memo (RM) scores. The team identifiers also show the gender (**F**emale, **M**ale, **N**on-binary) and race/ethnicity (**w**hite, **h**ispanic, **a**sian) of the students on the team. [The range of individual scores in brackets.] Note that blanks represent categories that weren't scored for particular RMs.*

Category	**Team F – Most ND; 2 Fw, 1 Mh, 1Nw**					**Team D – All NT; 1 Fw, 2 Mw, 1 Ma**				
	RM1	RM2i	RM3	RM4i	RM5	RM1	RM2i	RM3	RM4i	RM5
World view / outside connections		0 [0-0]	1	1.33 [0-3]	1.33		2.75 [0-5]	3	1.25 [0-4]	2.67
Project limitations	1		0.5	1.33 [0-3]		2		1	0.5 [0-2]	
Curriculum / water chem topics	4	0.67 [0-2]			3	1	1 [0-4]			1
Personal world view connections	3	1 [0-4]		1.7 [0-3]		0	0.38 [0-3]		2.75 [2-4]	
Stakeholder – centered design	3.5	4 [3-5]	2	1 [0-2]	3	2.5	3.25 [1-5]	0	3.25 [1-5]	1
Mentors			4	1 [0-2]				0	0.25 [0-1]	
TOTAL	**11.5**	5.7	7.5	5.7	7.3	5.5	7.4	4.0	8.0	4.7

Further in-depth analysis of the team RMs provides some interesting insights. On RM1, the ND Team F score was twice that of NT Team D. The RM1 from ND Team F discussed elements that mapped to all 4 of the relevant categories compared to only 3 categories in the RM from NT Team D. The learning depth was also richer in 2 categories. A similar pattern was found in team RM3, with 4 of 4 categories evident for ND Team F but only 2 categories for NT Team D. Team F showed level 4 thinking for the mentors' category versus a maximum of level 3 in the worldview category for NT Team D. On RM5 both teams had some evidence of thinking across all three applicable subcategories, but again deeper thinking evident in the RM from ND Team F (level 3 in both the stakeholder-centered design and curriculum topics compared to a maximum of 2.7 in the world view category for Team D.

Discussion

This research found that a team with a large amount of ND students excelled in group reflection assignments compared to a team without any ND students. In the context of classroom projects, these findings may indicate that teams with more divergent functionalities may perform strongest when working together, rather than separately, on assignments. These findings might reveal practical applications on how to integrate classroom activities to act as an academic intervention for ND students who otherwise might struggle with traditional learning environments. Utilizing assigned teams in the classroom and providing the option for teams to complete tasks independently or together opens the possibility for all different types of learners to perform to their best abilities.

Previous literature findings suggest ND individuals tend to produce "spikey" scores across different categories of brain functionality, producing graphs that appear to have "peaks" and "valleys". It is possible that the "peaks" that each ND individual on and ND team possesses affects the team's performance more than the "valleys", therefore leading to higher overall team success. In a broader context, these findings may suggest that teams predominantly composed of ND individuals may excel in work environments centered around the design process.

Previous literature findings also have suggested that ND individuals struggle in classroom environments due to their tendency to interpret directions and questions in different ways than they were intended. Therefore, a reason for the higher success rate of the ND students in groups may be attributed to the fact that the instructions did not specifically outline the categories that were graded in the charts. This could have allowed the students to ideate on the best ways they should answer the questions. ND students' different interpretations could offer a larger range of questions they believed should be answered from the prompt, therefore covering more of the categories in more detail.

The small size of the focus class and students' consent to participate in the research led to a small number of groups in the data set. Without having multiple similar groups to utilize to reproduce these results, the conclusion is limited to the uncertainty of the significance of the ND status as the main contributing factor. Many known factors such as race, gender identify, or year of study may have contributed to these results, but the sample size was too small to allow for control over these variables. Other unknown external factors may have also influenced the data, such as other classes the students had taken or were currently taking, or personal life happenings.
In Team F, one of the four students did not submit the individual RMs. The lack of individual performance scores may have skewed the average. These missing assignments may also indicate an unequal spread of workload across the team members.

Future Work

Future work will focus on two key areas of exploration. First, a systematic comparison will be conducted across all group types, including neurodivergent-only teams, neurotypical-only teams, and mixed neurotype teams. This analysis aims to identify patterns and differences in collaborative dynamics, problem-solving approaches, and creativity within each group composition. Second, the actual level of innovation achieved in the final team projects will be assessed through quantitative and qualitative measures. By evaluating these projects' originality, functionality, and impact, the study seeks to understand how team neurotype differences influence outcomes and contribute to engineering innovation. These efforts will provide deeper insights into the role of neurodiversity in fostering creativity and advancing engineering education and practice.

Conclusions

This study provides valuable insights into the potential benefits of teams with mixed neurotypes in educational settings, particularly in group reflection assignments and collaborative design tasks. The findings indicate that neurodivergent teams may excel in depth of analysis, breadth of coverage, and levels of thinking compared to neurotypical teams. The results suggest that the unique cognitive strengths of neurodivergent individuals, such as diverse interpretations of prompts and varied functional "peaks," contribute positively to overall team performance.

These observations align with previous research, which highlights the challenges neurodivergent individuals face in traditional learning environments and underscores the importance of inclusive instructional strategies. By fostering collaborative opportunities that leverage the strengths of neurodivergent learners, educators can create more equitable and effective learning environments. Additionally, this research suggests that teams with a high number of varied neurotypes may be particularly well-suited for tasks requiring creativity and design-oriented thinking, offering practical applications in both academic and professional contexts.

However, limitations in sample size and group composition necessitate caution when interpreting these results. Factors such as race, gender identity, year of study, and external influences were not controlled, and the absence of data from certain team members may have affected outcomes. Future research should expand the sample size and systematically explore the interactions between neurodiversity and other demographic and situational variables to validate and build upon these findings. This study contributes to the growing understanding of neurodiversity's role in education and highlights its potential to enrich collaborative and innovative efforts in engineering and beyond.

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