"Your brain is actually kinda wiggly": experiences of neurodiverse students in a large introductory physics class

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While neurodiverse students are a growing population in higher education, little discipline-based research focuses on their experiences. This paper presents a thematic analysis of interviews with three neurodiverse students in a large, discussion-based introductory physics class for physics majors at a large research university. We use a neurodiversity approach, which asserts that neurodiversity should be understood through the dual lenses of an individual's characteristics and their social environment. Through thematic analysis, we explore how their self-efficacy, peer connections, and access to support services influence and are influenced by the learning environment. Consistent with other work on neurodiversity, we observe a broad spectrum of experiences among neurodiverse students. We also identify challenges presented by the collaborative nature of the class. Our study underscores the need for further research into student experiences and the creation of inclusive learning environments.

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I. INTRODUCTION

While precise statistics on the number of neurodiverse students in university classrooms are hard to obtain, students identifying as neurodiverse represent an increasing portion of students pursuing higher education [1]. Work on supporting neurodiverse students in higher education settings has generally focused on institutional level supports [1, 2] and on principles of Universal Design for Learning (UDL) for pedagogy [3, 4], with substantially less work in discipline-based education research. Studies have highlighted that neurodiverse STEM students feel pressured to conform to neurotypical environments to avoid negative perceptions, with the stigma associated with a disability status introducing a large cognitive and emotional toll in having to mask or conceal their neurodiversity [5]. Recently, physics education researchers have begun to pay particular attention to neurodiverse students. James and colleagues [6, 7] have explored how students with ADHD learn in SCALE-Up classrooms, while McPadden and colleagues [8] have explored how to better design qualitative research methods in PER to include neurodiverse students.

The recent work by McDermott and colleagues [9] serves as a foundation for understanding the experiences of neurodiverse people in physics. Drawing on theoretical frameworks of neurodiversity [10] and previous works on Critical Physics Identity [11], McDermott and colleagues put for the Critical Disability Physics Identity framework. In this framework, neurodiversity is broadly defined as:

> "any identity that is grounded in differences in minds. That is to say, any identity that falls in the union of sensory and cognitive disability identity. These can include, but are certainly not limited to, autism, ADHD, MS, dyslexia, BPD, TBIs, Tic Disorders, epilepsy, etc" [9, p.3].

As with McDermott, we adopt a neurodiversity model for analysis built from the work of Dwyer [10, 12]. Rather than conceptualizing neurodiversity as related only to the traits of individuals or groups, the neurodiversity model argues for viewing neurodiversity as an interaction between individual's traits and societal structures. This approach recognizes that a neurodiverse individual may experience their neurodiversity both as a disability and as a strength depending on context.

We present a preliminary analysis of interviews with three neurodiverse students enrolled in a large introductory physics class. All three students initially intended to pursue majors in physics or astrophysics and had a broad range of experiences within the class. We identified three key themes across the interviews: self-efficacy, connection with peers, and access of support services. In line with work highlighting the heterogeneity in neurodiverse student experiences [13, 14], we find that the students experience the class very differently. While two of the participants expressed that peer interactions resulted in discomfort, the need to mask their neurodiversity, and feelings of low self-efficacy, a third described peer interactions as a source of positive feelings. Similarly, the students' interactions with support services varied from useful and empowering to frustrating and disempowering.

A. Author Positionality

Anna McLean Phillips (she/hers) is a white, straight, neurotypical senior lecturer in the School of Physics and Astronomy at Monash. She is also the Education Director of the school, which adds a dual purpose of her work her first and foremost responsibility is to the well-being of students within the School. She utilizes student data to shape the educational approaches within the School in addition to research purposes. Participants are informed of this dual purposes of data collection.

Thanura Ediri (he/they), a queer and neurodiverse undergraduate student, approaches this study as an "insider" researcher. However, diligent consideration must be given to prevent the confinement of participants' experiences by assuming that their experiences are identical to the researcher's irrespective of shared attributes.

II. CONTEXT, DATA COLLECTION AND DATA SELECTION

The interviews analyzed at this paper were conducted as a part of a broader, longitudinal study of students' experiences in the physics and astrophysics majors at a large research university in Australia. The students in this study were taking an introductory physics class for physics and other science majors with approximately 300 students enrolled, split into three roughly equal sections. The class is taught in a studio-style physics classroom, which is used for both "workshops," which are focused on group problem solving, and laboratories, which take place on a separate day. Content is provided through a combination of videos and readings.

During the first workshop of the semester, a survey was administered aiming to study a range of factors possibly related to retention. The survey also included a wide range of demographic questions, including separate questions about disability and neurodiversity, each with optional text boxes. Of the 247 surveys completed with research consent, 32 (13%) students identified as neurodiverse. Students were selected for interview recruitment if their survey indicated that they were a part of three or more minoritized groups in physics, including by gender, queer identification, disability identification, neurodiversity identification, low income status, minoritized ethnic and religious background, first generation status, immigration background, and rural/regional background. Of 36 students contacted, 17 participated in the initial round of interviews. Of these, a total of 8 self-identified as neurodiverse.

The present paper draws on two interviews each of three individuals. The first interview was conducted 3-5 weeks into the semester, and a second was conducted 10-12 weeks into the semester. The interviews were semi-structured, designed to capture a broad range of topics salient to students' experience in the introductory physics class. The first interview also included questions about students' experience in physics classes in high school and why the students were aiming to study physics. Set questions in the first interview included questions such as "Can you tell me about your high school

physics class?", and "How are the workshops and labs going so far?" The second interview included questions such as "How do you feel physics has gone this semester?" and "Was there a time in class when you felt included or excluded? If so, can you tell me about it?" When participants diverged from the initial question during the interview, the interviewer (Phillips) did not interrupt and only returned to the interview protocol once a participant naturally stopped discussing a particular topic. As a result, the interviews with each participant differed significantly. The interviews in the present paper all took place in person and were video recorded.

The present study's initial objective was to investigate the experiences of students who identify as both queer and neurodiverse. Therefore, at the start, six individuals who disclosed both identities were identified. As the intersection of neurodiverse and queer indentities as been indentified and explored in a range of literature (e.x. [15, 16]), this large number of participants with both identities was not unexpected. However, the queer identities of these students were not as salient, leading to a decision to focus the scope of the initial analysis focus on neurodiversity exclusively.

Subsequently, three individuals–Tom, Allison, and Ingrid–were selected to focus on for our initial work which is presented here. These three individuals were chosen as they represent a range of genders and 2 out of 3 identify with a racial/ethnic minority. These participants also had a range of experiences in the class. All three identified themselves as being autistic either in interviews or on the survey, with one also identifying as having ADHD. Further work will attend to all participants who identified as neurodiverse and queer and explicitly explore this intersection; however, that is beyond the scope of the present paper.

We intentionally obscure elements of our participants' identities to protect their anonymity. While discussing further social identities with an intersectional lens [17] of said participants would enrich the study, a conscious decision was made to omit these to protect participant anonymity in an effort to foreground participant well-being.

III. ANALYTICAL APPROACH

After each interview was performed, Phillips produced memos from memory to create a record of the interview. Additionally, automated transcriptions were made and archived. At the start of the analysis, Ediri watched the interviews with the six participants who identified as both neurodiverse and queer and produced further memos. From there, the three focus participants were studied. Ediri then produced annotated transcripts of the interviews with the focus participants. These initial annotations utilized discourse analysis and focused on understanding the content of students' speech and how that content connected to the broader context [18].

Next, a thematic analysis [19] was begun. Themes were initially identified by Ediri and refined collaboratively. Ediri tagged statements in the annotated transcripts connected to each theme. Statements were sometimes tagged with two themes. These themes were refined using literature on neurodiverse student experiences. The development of a coding scheme [19] is ongoing and will be presented in future work. The three primary themes identified across the participants were students' self-efficacy, their connections with peers, and their use of support services.

Self-efficacy, broadly referring to an individual's belief in their own capabilities [20], has long been studied in physics students, particularly with regard to women and other underrepresented groups [21–24], with researchers having identified links between self-efficacy and retention [22] as well as between self-efficacy and peer interaction [24]. In a range of higher educational settings, researchers have identified that neurodiverse students exhibit lower self-efficacy than their peers [2, 25], but that neurodiverse students' perceptions of ability also differ significantly along other demographic lines and are context-dependent. [26].

Connection with peers and peer recognition are connected to, though distinct from, self-efficacy. These links have been identified in physics education research by Dou and colleagues [24] who found positive relationships between self-efficacy and peer interactions. Students' connection with peers and sense of belonging have been connected to student retention and academic success [22, 27]. Work exploring neurodiverse students' connection with peers in higher education has identified that peer connection and support are both important to the success and wellbeing of neurodiverse students while also being fraught [28, 29]. While interactions with other neurodiverse individuals can provide support [29], masking, or the hiding of neurodiverse traits and behaviors, often takes a high toll on students [30, 31].

Support services can play a vital role in the experiences of students. However, there is often a disconnect between the support services that are available and students' interaction with them [3]. There have been reports of low usage of support services [14], compounded by stigma associated with accessing support services that can further exacerbate neurodiverse students' access to available support services [3, 32]. Most current support services rely on a needs-based approach, instead of a strengths-based approach that can serve as a barrier to accessing support services by putting the burden on the individual seeking support [33]. Some recent work in physics education research has addressed how to support neurodiverse students in classrooms. James and colleagues [6, 7] have studied how students with ADHD experience SCALE-UP classrooms, which are similar in structure to the class in this study. They suggested using UDL approaches and providing students with explicit instruction on how to develop conceptual learning, and further noted that students did not use accommodations due to social stigma.

IV. FINDINGS

A. Self-efficacy

Two of the participants showed context-dependent self-efficacy as described in Ref. [26]. Tom described feeling his success in the class was all or nothing: "If I'm not at the top of the class, I have no idea what's going on and it takes me so much time to be at the top of the class." While he describes

a binary view of his understanding in the class, he displays a growth mindset [34] when stating that it is possible for him to be at the top of the class. This binary view and growth mindset appeared in both interviews, with Tom connected feelings of having "no idea what's going on" to feelings of anxiety. Tom also described mastery experiences [20] in class, stating "I felt like 'can I do this"' even though "other people got it and I didn't at first." He continued, "I'm comfortable accepting that I might not understand it the same way and might learn differently to others, doesn't mean I'm not going to get it." His recognition that he learned differently from others supported his sense of competence.

Allison similarly described a range of feelings of competence. While she described herself as "capable" she linked this capability to ending up with an unfair share of tasks in group work, including in laboratories, "I hate it because I get the short end of the stick - you should have a neurotypical person sitting with you to say 'this isn't the time to say oh I can do that, I'm capable."' At other times, Allison described a lack of confidence in her ability to do work and communicate, particularly in writing, and she explicitly links this to her autism, "with the autism, I'm always double-checking myself." Allison displayed an awareness of how her self-efficacy was context dependent and linked this to her autism.

Like Tom, Ingrid describes understanding her neurodiversity as helpful for her self confidence. Ingrid described her experience of being diagnosed and how it helped her understand her learning process:

> "I went 18 years wondering 'why is brain not going in straight lines' and then finding out 'oh your brain is actually kinda wiggly and thinks in wiggly lines instead of straight lines, so we're going to have to work with it, instead of trying to fit it into something it doesn't.'"

She connected her diagnosis as opening up possibilities for improving her learning strategies, stating in the first interview "Throughout the year, I am going to be building new strategies to learn as efficiently and effectively as possible cause what's happening right now is not my full learning potential." For Ingrid, part of this strategy involved telling herself that she would be successful, as she noted, "If I don't go in optimistic, this is not going to work, I'm confident. I believe I can do it. I made all the way to uni. I can do it now." While Tom and Allison expressed self-doubt in their interviews, Ingrid frequently made statements of self-confidence.

B. Connection with Peers

All three participants explicitly addressed how they felt in connection with peers. This was unsurprising given that the interview protocol included questions about with whom they were working and the extensive work on how peer recognition and interactions shape students' physics identities [11, 35] . The students addressed this their experiences with peers at length, both in response to direct questions about their peers and in response to questions about how the class was going.

In the first interview, Tom expressed that he was "starting to make connections." However, he also alluded to struggling to interpret certain social cues, which can be a common experience for autistic individuals [36]. When talking about his experiences across classes, he said "there are a few moments where either this is a little awkward or we're all not sure what's going on and we all feel a little lost, or outright I feel like I'm being excluded or something weird is going on." Tom's challenges with discerning these scenarios may hinder his sense of belonging in the classroom, particularly given that this class is designed to maximise peer-to-peer interaction. While Tom does not know if he is being "outright excluded" or not, his experience suggests that this is a possibility shapes his interactions with peers. Tom further described frustration in navigating neurotypical environments and seeing his peers interacting and learning without any perceived barriers: "It can be a little bit isolating to look at other people interacting and learning and not having issues." Tom's perception that his peers were not similarly struggling contributed to an overall sense of isolation in the class.

Allison exhibited signs of social isolation to a much larger extent than Tom. She described her social isolation as relatively new and linked to the COVID-19 pandemic: "Before COVID, I'm pre-sure I had a social life and then after COVID I realised I didn't really need a social life. I tried to avoid people I classified as friends and I am trying to get to know them again because they're a good support system." Moreover, Allison was confronted with the struggles of assimilating to a neurotypical world and described her neurodiversity as an "issue." As a part of her support from university disability support services, Allison was entitled to use headphones in class for noise, yet she "didn't want to put on earphones and appear anti-social because I like to appear that I am completely neurotypical. I don't want to tell people that I have an issue." Her desire to mask was explicitly connected her desire to fit in and feel connected to her peers and had a direct impact on her access to available supports.

While Ingrid stated that her learning style differs from that of her peers, she also expressed a profound sense of belonging in the classroom. In the first interview, she said "I learn really differently from all the people I've met in physics." While acknowledging her differences in learning, she did not connect these differences to struggles in working with peers. In the second interview, she said "I felt really valued in the labs" when asked about peer interactions. Ingrid's positive interactions with her peers fostered an increased level of confidence and motivation to attend classes. Ingrid also described her connection with peers being driven by building a community of other women in physics. She described first day of workshop: "So like when I got here, and I saw a table full of girls, and I went, sat down. I was like, 'this is the most exciting thing that has happened to me.' Because in year 11, I spent my whole time with boys." Across multiple interviews, Ingrid expressed her enjoyment of finding community with other women, which may have lessened feelings of isolation due to her experience of learning differently from her peers. Interestingly, Ingrid's identity as a woman had a positive impact on her experience overall, possibly mitigating any

feelings of isolation arising from other aspects of her identity.

C. Access to support services

All three participants interacted with university services designed to support students with access needs with two further utilizing services designed to support students with other marginalized identities. Tom participated in a program through which he should have received a range of supports. However, a substantial amount of time and effort was required on his part to confirm his eligibility and then receive the supports. Tom described this frustrating situation as, "Students aren't getting the service you're supposed to be providing." He further expanded and noted that, "I feels like I'm struggling because not that physics is hard, but because of all of those factors." At other times, Tom expressed his frustration that his overlapping identities added multiple layers of disadvantage in his educational experience broadly. Because he had faced challenges in getting his diagnoses recognized by the university disability support office, he was further unable to access additional learning supports.

Allison's interaction with support services were more extensive and fraught than Tom's. Allison was openly resistant to the services offered. Due to Allison's difficulty with reading, "[Disability support services] said they could get a TA to read for me, but I didn't want to do this because I'm rebelling against cause just found out at uni that I couldn't read." Allison's discussion of "rebelling" hints at past negative experiences with support services and stigma associated with help-seeking [14, 37]. Allison also explained the cognitive load that is often required to access support services that are available: "I knew I had a lot of support but couldn't see a way of accessing them with the amount of time that I have available and within my comfort zone." In line with the students in the study by James and colleagues [7], a combination of social stigma and a desire to hide her neurodiversity reduces her utilization of available supports.

On the contrary, Ingrid perceived support in a very positive light and approached the opportunity to build strategies proactively and openly. This was evident in her description of her psychologist, as she stated, "I'm seeing a lovely lady once a month. I'm going to build on it over the next 4 months." In a later interview, Allison described the services from the university Disability Support Services as "great" and helpful in putting accommodations in place.

V. DISCUSSION AND CONCLUSION

The experiences of Tom, Allison, and Ingrid reveal the extremely heterogeneous experience of neurodiverse students In addition to their diverse experiences, they also experienced a range of outcomes: at the time of writing this paper, Tom was close to finishing his third semester of physics. Allison withdrew from of physics midway through the first semester. She felt positive about her choice, as she had discovered how much she enjoyed her other classes and wanted to switch her major. Ingrid dropped out of the second semester of physics, citing a lack of ability to learn the required mathematics and a lack of support in her mathematics classes. She described switching her major as "devastating." This range of outcomes highlights how the appearances of students' self-efficacy, connection with peers, and utilization of support services in the moment may not correspond to their ultimate outcomes. Despite her strong connection with peers, strong sense of self-efficacy, and active seeking of support, Ingrid was unable to continue with the major.

This preliminary work emphasizes the findings of others highlighting the heterogeneity of neurodiverse physics student experience [9, 14] and the challenges of providing appropriate supports [7]. While James and colleagues identified that the noise of studio-style classrooms may cause difficulties for students with ADHD [7], our work highlights that classrooms centered on peer interaction pose significant challenges to autistic students who may struggle with following social cues in class (such as Tom) or feel anxious and alienated by masking their neurodiversity (like Allison). Thus, physics classes designed with research-based best practices in mind may not be serving some neurodiverse students as well as others, putting them at an additional disadvantage.

This work highlights the need for additional research into the experiences of neurodiverse students and how they may experience different physics learning environments. Most physics education research tacitly assumes a neurotypical norm, rarely measuring or reporting neurodiversity. We join McPadden and others [8] in calling for more inclusive methods and studies across physics education research.

This work also raises questions about how to adapt frameworks that rely heavily on students' social experiences to accurately capture neurodiverse students. For example, Tom's description of not being able to gauge what is going on highlights how neurodiverse individuals may frame learning activities differently than their peers and may not pick up framing cues from those around them. Thus works on supporting students' productive framing in physics [17, 38–40] may not apply to neurodiverse students. Qualitative work grounded in interaction analysis and discourse analysis may have similar weaknesses: when theoretical and interpretive frameworks tacitly assume a neurotypical norm, we may misinterpret student discourse, leading to incomplete or inaccurate findings.

Overall, this preliminary work raises questions for both future research and pedagogical goals. We have no reason to believe that our student population–which has over 10% of the students identifying as neurodiverse–is an outlier. The large numbers of neurodiverse students highlight the importance of explicitly attending to neurodiversity in future research in learning and pedagogy.

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