A Systematic Literature Review of Neurodiversity in Engineering Higher Education

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Abstract—**This research paper (#1571006920) describes the preliminary findings of a systematic literature review. 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 that include but is not limited to: ADHD, autism, and dyslexia. Existing data on experiences and outcomes of neurodivergent students in engineering is limited and most likely underestimates the number of neurodivergent people in the sector. However, some evidence reveals that representation of neurodiverse people in engineering is far less than other STEM fields. This literature review seeks to clarify this gap in the literature and summarize what is known about neurodiversity in engineering education. We explored existing research and literature on this topic to answer the following research question: How has engineering education research explored neurodiversity in engineering context and specifically in relation to the structure and culture in engineering education?**

To address our research question, we performed a systematic literature review. First, we accumulated several articles in an initial database search of five databases. After identifying the preliminary set of articles, we performed secondary and tertiary rounds of inclusion and exclusion based on the applicability in addressing our research question. Then we performed categorical analysis on the remaining articles to explore main attributes that allowed us to examine possible trends between papers/studies and draw conclusions about how neurodiversity has been explored in the context of engineering.

Findings indicate that limited research exists on neurodiverse people's experiences and outcomes in engineering context and the specific role of engineering education structure and culture. Future work includes collecting empirical data aiming to understand the experiences of neurodiverse people in engineering context and understanding what/how/why the structures and culture of engineering affects diversity, inclusion, equity, accessibility and other outcomes for neurodiverse populations.

Keywords—*Neurodiversity, Neurodiverse, Higher Education, Engineering, Inclusion*

I. INTRODUCTION

Neurodiversity is a concept that regards neurological differences in brain function and behavior as part of the normal variation of the human population and are to be accepted and respected as any other human variation [1]. 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 that include but is not limited to: ADHD, autism , dyslexia [2] that all having associated challenges but also unique strengths [3] [4]. Neurodiverse [1] students are enrolling in post-secondary education at increasing rates but they continue to experience significant challenges which greatly impact their college life and their transitioning into the workforce [5] [6]. Yet strengths (e.g. visual thinking, original thinking, attention to details, deep interest and skills) and skills of neurodiverse individuals are that are in high demand in engineering and are essential to meeting current and future workforce needs [7].

Existing data on experiences and outcomes of neurodivergent students in engineering is limited and most likely underestimates the number of neurodivergent people in the sector. However, some evidence reveals that representation of neurodiverse people in engineering is far less than other STEM fields. One sample of college students with ADHD showed that only 3% were enrolled in engineering [8] and one sample of autistic students showed that while 34% were enrolled in STEM only 5% were enrolled in engineering [9]. However, underrepresentation of neurodiverse people in engineering fields and lack of feelings of inclusion, belonging, development of engineer identity among them have rarely been connected to the structures, systems and culture/climate within engineering higher education and workforce development. This literature review seeks to clarify this gap in the literature and summarize what is known about neurodiversity in engineering.

The purpose of this literature review is to gather literature surrounding neurodiversity within engineering higher

[1] Much debate on the language related to neurodiversity is still ongoing. Use of adjectives such as neurodiverse and neurodivergent is a personal decision that should be respected [4].

education. This serves the greater purpose of the study: to make clear that there is a gap in engineering education research on neurodiversity in engineering context and specifically in relation to the structure and culture in engineering education. To navigate the literature in this review, we use the guiding research question: **How has engineering education research explored neurodiversity in engineering education?**

II. Background

Disability, throughout most of its history, has been understood within the context of diseases and deficits. Integrative models of disability, however, leaves room for the corporeal realities of physical, cognitive, or psychological needs, but understand disabilities as outcomes of structures and systems with physical, cultural, and organizational arrangements that dis-able some people but not others [10]. Strengths-based approaches to neurodiversity take, as a starting point, the assumptions of the social model of disability and then translate them into approaches that support, educate, or enable people with disabilities to function successfully in typical contexts.

Engineering has long been perceived as dominated by white, heterosexual, able-bodied, middle-class, US-born cisgender men, with several marginalized and minoritized statuses, including disability, widely underrepresented and alienated [11], [12], [13]. Engineering education scholars have documented the marginalization and minoritization of women, people of color, and sexual and gender minorities [14].However, the experiences and voices of neurodiverse engineering students have scarcely been explored within engineering education research and very little is known about how neurodiverse students may face constraints, burdens, biases, and discrimination within engineering education culture/climate.

The campus climate and culture of engineering schools with ‘ableism’ and ‘typicality’ deeply rooted in its physical, temporal, and epistemic norms, have assumptions about bodies and minds through which recognize (or dismiss) one's skills, abilities, and potential as an engineer and thus can contribute to the social exclusion and professional devaluation of neurodiverse students, factors of which are key predictors of performance and persistence [14] [15].

Additionally, even with strong supportive climate, the struggles faced by those with neurodiversity in traditional pedagogy that is still widely practiced in engineering education, can be obstacles to equity, inclusion and accessibility for neurodiverse students [16]. For an instance, engineering education commonly require students to submit written homework to demonstrate understanding. Whereas, to address varied learning styles and social preferences of neurodiverse students, accessible pedagogical practices, such as the Universal Design for Learning, recommend allowing students to have autonomy in the way they demonstrate their understanding [17]. Additionally, it is also still understudies what/how elements of less traditional engineering education including project-based learning, working in teams, and co-op based learning are associated with experiences and outcomes of neurodiverse students.

Despite its importance, engineering education research has largely ignored the components of engineering structures, systems and culture/climate that can have negative or positive impacts on inclusion, accessibility and retention of neurodiverse engineering students. Premised on this, it is critical to understand how engineering education has explored neurodiversity specifically in association with engineering structures and culture.

III. Methods

A. Methodology

We followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guideline for this paper [18]. This review is part of a larger project that aims to review neurodiversity in STEM higher education. To begin, we refined and finalized our search terms and selection of databases through consultations with two librarians and by conducting several test searches to optimize our strategy. Ultimately, we conducted a comprehensive electronic literature search across five major databases, using a set of search terms designed to capture the broad spectrum of relevant studies. We performed first and secondary rounds of exclusion on the accumulated articles by reading their title/abstract and then methods. After excluding all articles that were out of the scope of the literature review, articles specifically focused on engineering were pulled out. Then, we performed tertiary round of exclusion on the remained articles by reading through their full-text and determining if they addressed our review question. We performed two categorical analyses on the included articles.

B. Data Collection

The data collected in the systematic literature search were from papers from the following five (5) databases covering articles published until March 2024: Education Full Text, Education Research Complete, ERIC, PsycINFO, and Scopus.

Three categories of terms and keywords were used, including:

- “Neurodiversity” OR 26 other keywords, e.g., autism or neurodevelopmental.
- “STEM” OR 20 other keywords, e.g., science or engineering.
- “Higher education” OR 8 other keywords, e.g., undergraduate or university.

The title or abstract of articles should include all these three categories. When possible, we limited our search to peer-reviewed publications written in English. The initial search in five databases yielded accumulated 2688 articles. Then, 484 duplicate articles were removed resulting in 2204 initial articles.

After an initial search through the databases, we screened the papers based on reading through titles and abstracts for key words and phrases. Then, we analyzed the remaining articles with secondary and tertiary rounds of exclusion based

on how well the papers answered our research question. The secondary round of exclusion involved reading through the methods section to explore if the article includes our target population (i.e., neurodiverse student, faculty, or staff in any of STEM fields higher education). After excluding articles based on this criterion, 103 articles remained in the literature review. In the next step, articles that included population in engineering fields, were selected. Lastly, a final round of exclusion was performed involving a full read of the 43 papers to narrow down the articles specifically focused on engineering education. If the paper did not focus on the experiences of neurodiverse populations or neurodiversity-related instances in engineering higher education, it was excluded. The initial 2204 articles were narrowed down to 10 articles that satisfied the inclusion and exclusion criteria. Then, we included a snowball sampling strategy where we identified additional articles through forward citation and reference searching. This involved identifying articles that cited the included articles and checking the reference lists of those articles. An additional 3 articles were included, in the review, resulting in a total of 13 articles for review. A flow chart of the selection process is presented in Figure 1.

C. Data Analysis

Once we determined the final set of articles, we analyzed the data through a "synthesis" process involving mapping papers into categories, which were recorded in a table. We performed categorical analyses to compare each article across multiple groupings of attributes. The first categorical analysis involved sorting each paper into two categories based on whether or not the experiences of neurodiverse population in association with engineering education structures, systems, and culture/climate was the focus of the paper.

The second categorical analysis involved the extraction of several attributes of each paper including theoretical framework, methodology, target population, and article type. These attributes were described in a table that laid out each article and its contents. This table allowed us to examine possible trends between papers. Together, these categorical analyses helped us to draw conclusions about how neurodiversity is studied in engineering higher education research.

D. Quality

The research team maintained quality throughout the literature review process. First, we kept careful documentation of the literature review methods so it may be replicated or reviewed by future team members or outside researchers. This included shared documents for detailing findings, and spreadsheets showing each step of the data analysis process (exclusion steps and each categorical analysis). Next, the research team met at weekly intervals to update everyone on progress made and make plans to accomplish our research goals on time and to review the process by Borrego et al. [19] to stay aligned with the methodology of the literature review. Lastly, we delegated tasks such that at least one other researcher could review others' work. Through the processes of recording, documentation, and multiple reviews, the research team ensured the literature review was robust.

IV. Results

The analysis of the literature based on the first categorical analysis yielded two key findings. First, among the 13 papers in the literature review, only one of them looked at engineering higher education systems and structures as a factor associated with access to engineering education [15]. However, this paper was a preliminary study including the narratives of only one ADHD student and neurodiversity was not the main focus of the paper but disability broadly. Second, among the other 12 studies, authors of some papers discussed engineering structures, systems and culture/climate to explain their findings and/or as factors associated with experiences of neurodiverse populations in engineering higher education (e.g., [20] [16]). Yet they did not aim to explore and understand what/how engineering education structures and culture affect inclusion, equity, and accessibility and other outcomes for neurodiverse populations.

Based on the first categorical analysis, while none of the papers in this literature aimed to explore and understand what/how engineering structures and culture is associated with experiences and outcomes specifically for neurodiverse students, those are common factors mentioned and discussed in literature. Together, these findings reveal a potential gap in the literature regarding focusing on diversity, inclusion, equity, and accessibility for neurodiverse populations in relation to structures, systems and culture within engineering education.

The analysis of the literature based on the second categorical analysis revealed that, out of 13 papers, nine were conference papers and almost all reported preliminary studies [15] [21] [22] [20] [23] [24] [25] [26] [27]. Of the four journal articles, one didn't aim to answer neurodiversity-related questions, but student reported having ADHD was examined as a factor, amongst other factors, that may explain retention of first year engineering students [28]. In another journal article, authors explored usefulness of educational data mining methods to predict stability of academic behavior of undergraduate engineering students based on having learning disabilities and accommodations [29]. Although this study has implications for colleges and faculty to choose the appropriate accommodation to give a student with a learning disability, the paper main aim is to evaluate the usefulness of the methodological model. Two other journal articles both aimed to explore creativity strengths of ADHD undergraduate students [30] [31]. Though a theoretical framework were not clearly utilized in most papers, social-relational models of disability, anti-ablism, and strength-based approach to neurodiversity was discussed in several studies (e.g., [15] [31] [20]), clearly showing a need for paradigm shift from medical models to an integrative model of neurodiversity.

Another finding was that compared to ADHD population, little research is done regarding students with autism, and little more is done including students with learning disabilities. Additionally, none of the 13 papers included experiences of neurodiverse faculty and staff in engineering education.

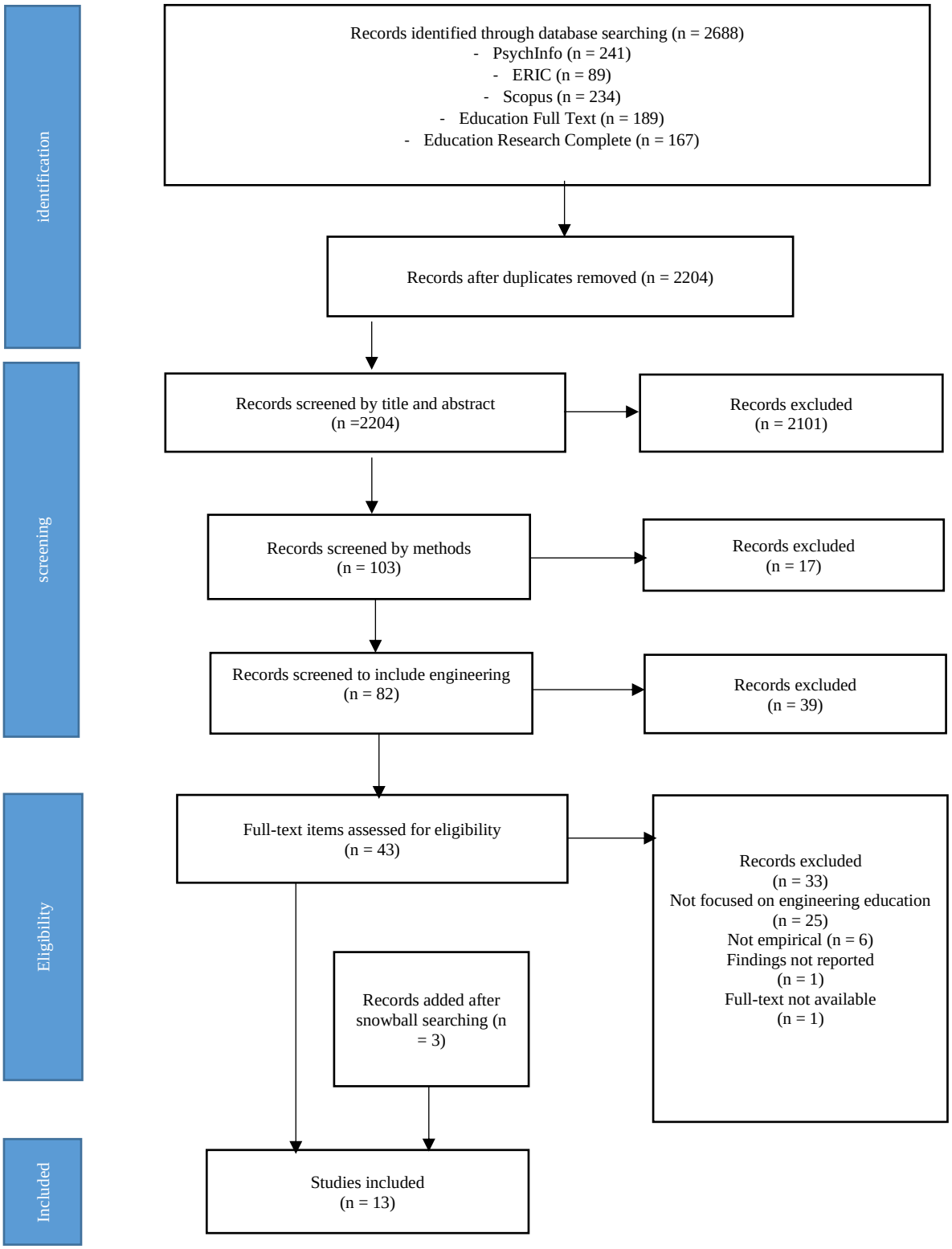

Fig 1: PRISMA flowchart indicating the literature search process

The last finding that resulted from this literature review is the variety of methodology types in the papers in this literature review (See Figure 2). However, most papers lacked a clear explanation of methodology. These numbers show that all three methodologies are relatively represented in literature, showing that the research community is interested in the topic enough to approach it in multiple ways.

V. Discussion and Future Directions

With this literature review, we sought to investigate how engineering education research has explored the experiences of neurodiverse populations and neurodiversity-related instances specifically in association with structures and culture within engineering higher education. To address our research question, we performed a systematic literature review including a multi-round exclusion to find papers that

fitted our inclusion and exclusion criteria. Categorical analysis of the articles showed that none of the papers in this review aimed to investigate what/how engineering structures, systems, and culture affects diversity, inclusion, equity, accessibility and other outcomes for neurodiverse populations in the context of engineering education, specifically.

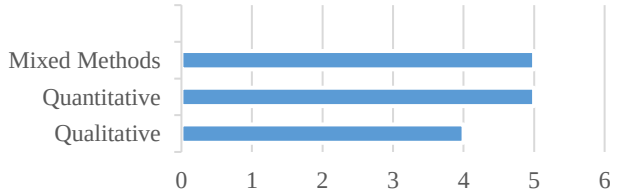

Fig 2. Paper counts according to methodology type

Although this specific topic was not centered in any of the studies, this literature review revealed that engineering context repeatedly was discussed in studies. Together, these findings reveal a gap and a need to understand how systems, structures and culture/climate and the default educational practices in engineering may be associated with different outcomes for neurodiverse students, faculty and staff. This paper also revealed that autistic students' experiences have scarcely been studied, and little more is done on students with learning disabilities. Although ADHD students were more represented in papers, they are like other neurodiverse populations underrepresented in engineering education research.

Altogether findings of this review study suggest there is a gap in the literature on multiple levels. There is a gap in research on neurodiversity in general, and there is a gap in research aiming to understand why engineering structures and culture are not neuroinclusive. This study also reveals a need to understand how the elements of less traditional engineering education, e.g., project-based learning influence inclusion, equity, and accessibility for neurodiverse populations and how universal design for learning can be implemented within engineering education.

Future works should focus on neurodiversity in engineering context, utilizing more sophisticated methodologies and an integrative model, to advance knowledge and highlight how structures, systems and culture/climate and the default educational practices in engineering may influence experiences and outcomes for neurodiverse populations in engineering higher education. In addition, future research should aim to apply the knowledge obtained to address the critical gaps in the preparation of engineering faculty, ensuring they are equipped to facilitate full inclusion in teaching and advising neurodiverse students, and improving the education of employers in order to challenge the neurotypical expectations that are prevalent in engineering higher education and the workplace.

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