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A Scoping Review on Non-Majority Students' Sense of Belonging in Engineering and Computing Education: Uncovering the Barriers, Needs, and Contexts

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A Scoping Review on Non-Majority Students' Sense of Belonging in Engineering and Computing Education: Uncovering the Barriers, Supports, and Contexts

Abstract

This work-in-progress theory paper discusses the preliminary findings of a scoping literature review on non-majority students' sense of belonging in engineering and computing education, focused on barriers, supports, and contexts. A substantial body of research underscores the significant impact of sense of belonging on students' educational, social, and psychological outcomes, particularly for non-majority students in engineering and computing education who often experience isolation, which in turn impacts their decisions to leave their fields of study. Consequently, sense of belonging research has become more prevalent in engineering and computing education to challenge racial and socioeconomic disparities, leading to a recent surge of interest and publications in the field. This work is part of a larger literature review project on a sense of belonging in engineering and computing education, focusing on the barriers, needs, and infrastructure that help non-majority students develop a sense of belonging. While this review is ongoing, we present some preliminary findings to share with the research community and solicit feedback as we continue our study.

Introduction

Sense of belonging (SB) is one of a number of ways to the fundamental human need for social bonds and connections [1], [2]. Although SB has been defined and theorized in diverse ways, this construct is distinguished as a subjective feeling that "persons feel themselves to be an integral part of that system or environment" [3, p. 173]. Within education and educational psychology, ensuring that students develop SB within diverse educational settings and with the subject of study has been considered crucial for their success [4]–[7]. Despite SB's importance and growing attention, non-majority students (i.e., individuals whose demographic backgrounds are not shared by a majority of the STEM community) still face difficulties in cultivating SB to their community, field of study, and institution. Studies within STEM education have found that non-majority students face specific cultural barriers to developing SB [8], [9].

SB research within engineering and computing education has started to gain momentum, with a majority of the research being published in the last four years [10]. While this is promising for shifting engineering and computing education from the emphasis on diversity to inclusion of diverse student populations within the fields, the community would still benefit from a review of the recent SB literature with a particular focus on non-majority students whose SB is more vulnerable. Generating a synthesis of the current research focused on the students' perceived barriers and supports regarding SB in diverse educational contexts (e.g., classroom, institution, study field, etc.) for varied student groups (e.g., undergraduate vs. graduate, different non-majority student groups by gender, race/ethnicity, etc.) will contribute to support non-majority students in engineering and computing education to develop SB.

Current Study A viable first step in bridging this gap is to comprehensively map the existing literature on non-majority students' SB, focusing on common needs and barriers, as well as identifying any differences that may exist between student populations, which this study aims to address. Our team has been conducting a synthesis research project on SB in engineering and

computing education, and a portion of the data collected for this larger project will be used for the current scoping review. A scoping review was considered an appropriate method for this study, as the goal of this research is to report the current state of the literature, as opposed to synthesizing forms of practice or areas of future research [11].

Methods

The larger synthesis research project was guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines [12], as well as a pilot scoping review conducted by the research team [10]. We began by screening abstracts of our gathered literature from six selected academic databases (Web of Science, Engineering Village, ERIC, Academic Search Complete, APA PsychINFO, and ACM Digital Library) using Boolean search strings that are shown in the Appendix. We used a total of four Boolean search strings that were developed with aid from our engineering librarian for each database to ensure that we were able to obtain all relevant articles for the scoping review. We used Covidence©, a scoping and systematic literature review management website, to aid in our abstract and full-text review. Based on our inclusion and exclusion criteria, we identified relevant literature from January 2015 to August 2024, provided it was written in English, published as a peer-reviewed journal article or conference proceeding, and focused on student populations in the context of engineering and computing education.

During our larger review, we noticed several papers that focused on non-majority students' experiences and how to help these students develop SB. Considering the importance of this topic, we chose to explore this area in more detail and conduct a deeper review of the literature in this area. More specific inclusion and exclusion criteria for this project were that the research had to focus on non-majority students' SB and whether the research project was exploring barriers to developing SB and/or attempting to develop or determine a support system for developing SB within students. At the time of writing this paper, we have finished reviewing abstracts and are currently conducting the full-text review, with 25 papers reviewed in full. In this work, we report the current findings of the ongoing full-text review, specifically those related to the barriers, supports, and contexts for developing SB in non-majority students.

Results and Discussions

A total of 22 papers were included from the 25 articles and proceedings reviewed, as three papers were found to not meet the additional inclusion criteria as part of the full-text review. An additional five were not considered relevant to the focus of the current scoping review – *Barriers, needs, and contexts relating to SB in non-majority students in engineering and computing education* – resulting in 17 papers for the current work-in-progress scoping review. Of these papers, 13 were conference proceedings and four were journal articles. A relatively higher number of conference proceedings compared to journal articles aligns with the results of our pilot scoping review on SB research in engineering education [10], providing additional evidence of the growing field of SB research, with conference proceedings potentially serving as preliminary work for journal articles. Seven of the reviewed works related to computing students' SB and three were interested in graduate students' SB. Below is a more detailed

description of the findings related to the barriers, supports, and contexts of developing SB within non-majority students.

Barriers Within the literature reviewed, variables related to individual student attributes and the engineering and computing education system were seen as barriers for non-majority students to develop SB. First, a lack of individuals with similar backgrounds was discussed as a barrier for SB. For example, a study found that when female computing students worked in groups that did not contain others of the same gender may feel that they belonged less than their peers [13]. Similarly, when looking at male international graduate students, researchers noted that these students felt they wouldn't belong to their field of study if there were not others in their research group who shared a similar cultural background [14]. Second, competitive environments in engineering education where students feel that they must be compared to each other also act as a barrier to SB [14]. The authors noted that students felt that social interactions were not between peers but with competitors, limiting the amount of SB for all but the top students in the department.

Supports Most of the literature reviewed in this paper was related to developing or improving support systems for non-majority students. Particularly, a majority of the work reviewed here was focused on the development or implementation of classroom interventions designed to increase SB among undergraduate students, especially first-year students [15]–[22]. The findings show that some interventions had no effects on SB [19], small effects [15], [18], or were too early in their project to present any findings [16], [22].

That being said, the classroom intervention literature found several results that relate to the current focus. In an intervention designed to introduce students to a makerspace before working on their engineering projects, researchers found that Hispanic students had the largest gains in their sense of belonging to the makerspace [21]. Researchers also found that revamping the introductory computer science course to focus on more active learning exercises, diversifying the TA team, placing students in lab sections with similar levels of experience and comfortability with coding, and adding an additional exam greatly improved women's performance in the course [18], possibly due to students being able to relate to their peers of similar experience as well as seeing others of similar demographics in leadership roles. Using an ecological belonging intervention in an introductory engineering course was also found to increase Black, Hispanic, and Indigenous students' academic performance, suggesting that normalizing struggle can give students a persevering mindset related to their studies [15].

Outside of the class structure, another support system discussed in the literature was systematic support from the institution, such as inclusive mentoring programs focused on non-majority students. Providing faculty and peer mentoring to first-generation college students was found to promote confidence and SB within biomedical engineering [23]. Lopez and Dey also called for mentoring programs to help support non-majority students in STEM [24]. Other researchers showed that certain teaming behaviors, such as strong team relationships, supportive intergroup relations, passion and commitment among team members, shared purposes and goals, establishing and valuing differing roles in the team, and shared personal responsibility help to promote a sense of community among first-year engineering students [20].

Contexts Regarding context, much of the work reviewed in this paper focused on the classroom as the major context in which SB is built [15], [16], [18], [19], [25], which may be potentially related to the educational level of participants in the selected articles for the current preliminary review. Other work related more to the field of study [14], [23], and one that was specific to a makerspace [21]. It is interesting to note that in this last paper, SB to the makerspace increased in students when introduced the makerspace, but their SB to the engineering community did not change significantly, generating evidence on the context-specific characteristics of SB. The years of study, however, was correlated with higher SB to the engineering community [21].

Limitations, Implications, and Conclusions

We clearly indicate that there is a limitation due to the nature of this preliminary synthesis, which used a small subset of the full data. However, this work is important for moving forward by providing a better understanding of where to focus and what to consider in the main synthesis. Based on the lessons learned from this preliminary synthesis, future work will be to conduct a more systematic review, considering potential differences in barriers and supports depending on student groups and/or educational levels, as well as similarities or differences in terms of study context between the fields (i.e., engineering education versus computing education) of research published.

We report our preliminary findings related to the specific barriers, supports, and contexts related to non-majority students and their development of SB. According to our preliminary synthesis, there are three main takeaways that are important to consider. First, methodologically, a majority of the quantitative work that we reviewed was limited in that there were relatively low sample sizes. Many of the quantitative research projects that were reviewed noted that the findings are limited due to the low number of participants, especially non-majority participants, in the study [15], [18], [21], [26]. Such limitations are common when studying non-majority groups within STEM and so finding a way to collect data allowing for robust quantitative analysis would be key to gathering more data in this manner.

Second, since SB is context-dependent and multifactorial, we are interested in exploring how researchers attempt to measure SB in different contexts. For example, Andrews and colleagues measured students' SB to the makerspace and to the engineering community, finding that different factors were correlated with each [21]. These types of findings can be valuable to the field, where the conceptual knowledge on the dimensionality of SB and the consequential use of measurement is still being established, and should be encouraged moving forward to get a broader understanding when appropriate.

Third, we are interested to see if our review yields more results related to the students' perceived barriers in developing SB, rather than the support structure developed by others. Based on the review of the selected 25 articles (out of 366 articles for the main synthesis), only three works investigated barriers for non-majority students and their SB development [13], [14], [27]. Considering that identifying the barriers faced by non-majority students is a crucial first step in developing appropriate and effective support structures, our future synthesis will place greater emphasis on properly identifying and categorizing the barriers for different non-majority student groups in engineering and computing education.

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Appendix. Boolean Search Strings

Table 1.

Boolean Search Strings Used in the Current Scoping Review

Number	Boolean Search String
1	(belonging OR belongingness OR "sense of belonging" OR "university belonging" OR "social belonging" OR academic belonging”) AND (“engineer* educat*” OR “computing educat*” OR “computer science educat*” OR “engineering student*” OR “computing student*” OR “computer science student*” OR “engineering undergraduate stud*” OR “computing undergraduate student*” OR “computer science undergraduate stud*” OR “engineering graduate stud*” OR “computing graduate student*” OR “computer science graduate stud*” OR “engineering facult*” OR “computing facult*” OR “computer science facult*” OR “engineering communit*” OR “computer science communit*”)
2	(connectedness OR "student connectedness" OR "campus connectedness") AND (“engineer* educat*” OR “computing educat*” OR “computer science educat*” OR “engineering student*” OR “computing student*” OR “computer science student*” OR “engineering undergraduate stud*” OR “computing undergraduate student*” OR “computer science undergraduate stud*” OR “engineering graduate stud*” OR “computing graduate student*” OR “computer science graduate stud*” OR “engineering facult*” OR “computing facult*” OR “computer science facult*” OR “engineering communit*” OR “computer science communit*”)
3	(relatedness OR "student relatedness" OR "academic relatedness" OR "social relatedness") AND (“engineer* educat*” OR “computing educat*” OR “computer science educat*” OR “engineering student*” OR “computing student*” OR “computer science student*” OR “engineering undergraduate stud*” OR “computing undergraduate student*” OR “computer science undergraduate stud*” OR “engineering graduate stud*” OR “computing graduate student*” OR “computer science graduate stud*” OR “engineering facult*” OR “computing facult*” OR “computer science facult*” OR “engineering communit*” OR “computer science communit*”)
4	(“sense of inclusion” OR “social fit” OR membership) AND (“engineer* educat*” OR “computing educat*” OR “computer science educat*” OR “engineering student*” OR “computing student*” OR “computer science student*” OR “engineering undergraduate stud*” OR “computing undergraduate student*” OR “computer science undergraduate stud*” OR “engineering graduate stud*” OR “computing graduate student*” OR “computer science graduate stud*” OR “engineering facult*” OR “computing facult*” OR “computer science facult*” OR “engineering communit*” OR “computer science communit*”)