

Sense of Belonging in Large Online Engineering Classes: A Scoping Review

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Sense of Belonging in Online Engineering Classes: A Scoping Review

Abstract

The purpose of this study was to describe the state of existing scholarship on sense of belonging in online undergraduate engineering education courses, particularly as it relates to efforts to promote diversity, equity, and inclusion. The guiding research question was: In what ways has scholarship addressed potential interrelationships between sense of belonging; diversity, equity, and inclusion; and online undergraduate engineering education? We used a scoping review to examine the extent of available peer-reviewed literature and identify research gaps at the intersections of these areas. We searched for journal articles and conference papers in two databases, Education Research Complete from EBSCOhost and Engineering Village, established inclusion criteria, and examined the characteristics and findings of qualifying studies. We identified modest evidence of peer interaction and instructor-student interaction in online courses, as well as a few tips for instructors seeking to increase student engagement in online courses using instructor-led synchronous chats, audio-based formative feedback, and the use of a virtual environment and avatars in sense of belonging literature. Sense of belonging remains largely unexplored in online undergraduate engineering classes and underrepresented students within those classes. We offer implications for faculty seeking to promote more culturally responsive teaching and assessment practices in online undergraduate engineering classes by creating a sense of belonging.

Introduction

In mid-Spring of 2020, the worldwide COVID-19 pandemic prompted most universities to abruptly shift to offering classes online. Before that shift, many faculty lacked online teaching training and experience, and “97 percent of institutions moving classes online had to call on faculty with no previous online teaching experience” [1]. Prior to COVID-19, only 60% of university chief online officers said faculty were required to have some formal training prior to teaching online [2]. Faculty teaching in undergraduate engineering programs were tasked with handling large class sizes, strict pre-requisite requirements, and heavy technical content as they converted their courses to online formats. In addition, many engineering programs were also struggling with issues of diversity, equity, and inclusion, particularly of student populations underrepresented in STEM fields, a challenge that would be magnified since retention rates in online education are often lower than in face-to-face classrooms [3], [2]. The pandemic heightened educational disparities, including racial inequalities in higher education [4], [5].

As engineering educators adapted their classrooms for online learning, we explored the engineering education literature for research that would offer guidance in creating learning environments in which students could engage with both subject matter and their peers and professors. Our review focused on how underrepresented minority students could be best supported. We began with Strayhorn’s [6], [7] model for sense of belonging, which posits that the ‘belongingness’ component of Maslow’s [8] hierarchy of needs is not only a human need but also a motivating force that influences behavior. Strayhorn and others who have extended the framework have found that a student’s cognitive and emotional engagement in campus culture is linked to success. This engagement may be even more impactful for students who are

acclimating to a new setting culturally, such as first-generation and underrepresented minority students. Considering pandemic-enforced online learning drastically reduced the richness of campus culture and opportunities for engagement, we believe that exploring the attention to interaction with peers and professors in classes is a critical task for engineering education research to address.

With the goal of targeting scholarship at the intersection of sense of belonging and undergraduate online engineering courses, we conducted a scoping review with the following research question: *In what ways has scholarship addressed potential interrelationships between sense of belonging; online undergraduate engineering education; and diversity, equity, and inclusion?*

Literature on Sense of Belonging

Maslow [8] explained that after physiological and safety needs are met, the need for love and to belong emerges. Belonging is necessary for all human beings to achieve their full potential. The construct of belongingness was well established by the early 2000's and has been applied in school and college settings (see Strayhorn [7] for a comprehensive review). Strayhorn [7] defines sense of belonging as “students’ perceived social support on campus, a feeling or sensation of connectedness, and the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the campus community or others on campus such as faculty, staff, and peers” (p. 4).

A student’s sense of belonging is key to their collegiate success, including academic achievement and persistence. Belonging is felt with peers, in classrooms, and in the college environment. Moreover, faculty members convey care for students in many ways that help develop their sense of belonging, such as learning and remembering students’ names, taking note of students’ career goals, and emphasizing the value students add to class discussions [7], [9]. Cultivating a sense of belonging in students has several documented advantages. Sense of belonging is positively associated with retention and persistence [10], self-efficacy [11], and a successful transition to college [12]. When sense of belonging is lacking, students’ academic performance suffers [9].

Sense of Belonging in Online Environments

Pilcher [13] extended Strayhorn’s [7] sense of belonging work and applied it to a review of the literature on establishing community in online learning spaces. Two models of community development in online learning spaces emerged in Pilcher’s [13] literature review: (1) a conceptual framework called Community of Inquiry (COI), which explains that teaching, social, and cognitive presence contribute to community development, and (2) a measurement model called Rovai’s Classroom Community Scale, which measures social and learning community, including students’ sense of belonging, in online courses. In both of these models, the instructor is the key component to establishing a sense of community in online classrooms.

Two methods to create a sense of belonging for students in an online course were recommended, online discussion board posts and peer review of written assignments. Faculty can model introductions at the building of class through guided prompts, use discussion boards to allow students to get to know each other and build trust, and then include guiding questions to facilitate

peer review of each other's papers before assignment submissions [14]. Though these suggestions are helpful in a broad sense, parsing out how such strategies impact STEM (and specifically engineering) students from different backgrounds is needed.

Sense of Belonging in STEM/Engineering

Sense of belonging is especially critical in unfamiliar contexts and places where people feel marginalized [7]. Students of color attending a predominantly White institution, students of color in STEM, and women in STEM are examples of groups of students that have historically been marginalized in higher education. Strayhorn found that "sense of belonging in STEM was significantly (and statistically) related to students' self-esteem and the frequency of their interactions with peers" [7]. Students of color in STEM fields may have a particularly difficult time fitting in because they are "one of very few" [7].

Sense of Belonging by Social Identities

More recent research shows that belonging differs based on an individual's social identities and their intersections, such as race, ethnicity, social class, first generation status, sexual orientation, and gender identities [7]. For example, Latinx students in particular who feel validated, supported, and valued are more likely to feel like they fit in [7]. The significance of belongingness to student success and mental health is especially critical for first-generation students [15].

We undertook a scoping review of the literature on sense of belonging in undergraduate online engineering education to better understand the available research on creating a sense of belonging for students' academic achievement and persistence.

Theoretical Framework

Strayhorn [6], [7] built on Maslow's [8] hierarchy of needs to argue why it is needed in college experiences related to student learning outcomes. Pilcher [13] extended Strayhorn's [6] sense of belonging work and applied it to a review of the literature in online learning spaces. Our paper explores the intersections of Strayhorn's sense of belonging and related concepts, online learning spaces, and STEM courses, specifically in engineering classes.

Seven assumptions guide Strayhorn's [6] theory of sense of belonging:

1. Sense of belonging is a basic human need.
2. Sense of belonging is a fundamental motive, sufficient to drive human behavior.
3. Sense of belonging takes on heightened importance (a) in certain contexts, (b) at certain times, and (c) among certain populations.
4. Sense of belonging is related to, and seemingly a consequence of, mattering.
5. Social identities intersect and affect college students' sense of belonging.
6. Sense of belonging engenders other positive outcomes.
7. Sense of belonging must be satisfied on a continual basis and likely changes as circumstances, conditions, and contexts change.

Strayhorn's [6], [7] sense of belonging framework informed this scoping review, especially in how we chose which articles to include.

Methods

We performed a scoping review to address our research question. A scoping review is an exploratory project that systematically maps "the literature available on a topic, identifying key concepts, theories, sources of evidence and gaps in the research" [16]. Scoping reviews are frequently used in public health or policy studies [16], and have recently been applied to STEM education [18]. Scoping reviews are commonly used: 1) to map the extent, range, and nature of available research, 2) to determine the value and feasibility of conducting a full systematic review, 3) to summarize and share research findings, or 4) to identify gaps in literature [19].

Like Denton and Borrego [18], we followed Arksey and O'Malley's [19] five-stage framework for scoping reviews by: 1) identifying the research question, 2) identifying relevant studies, 3) selecting studies, 4) charting the data, and 5) collecting, summarizing, and reporting results.

To address our overarching research question, *In what ways has scholarship addressed potential interrelationships between sense of belonging; online undergraduate engineering education; and diversity, equity, and inclusion?* We identified the following focus questions:

When considering online, undergraduate engineering class environments at four-year colleges and universities:

1. How is the conceptual framework of 'sense of belonging' addressed in research studies?
2. What pedagogical methods and practices are used to promote a sense of belonging?
3. What pedagogical methods and practices are used to promote diversity, equity, and inclusion?

Our research questions align with two justifications for conducting a scoping review [19]. First we aim "to examine the extent, range and nature of research activity" (p. 21) and, because the intersections of our search have a relatively brief history in scholarship, we also expect to identify research gaps in this process [19].

Inclusion Criteria

To identify relevant studies, we established our inclusion criteria using an iterative process, as is appropriate for scoping reviews [19]. Our inclusion criteria that each source must:

- IC1: Address sense of belonging or a related concept such as community.
- IC2: Focus on engineering or STEM (including engineering) undergraduate education.
- IC3: Focus on a four-year or bachelor's program.
- IC4: Focus on formal, online education.
- IC5: Be published between 2010 to 2020.
- IC6: Be published in a scholarly, peer-reviewed journal or conference article.

For IC1, we searched for terms related to “sense of belonging” and belongingness. After reviewing Pilcher [13], we added the terms engagement and “sense of community” to our search. Literature on sense of belonging as a need for student success was established by 2010. Moreover, the articles we reviewed that were published around 2010 referred to distance education in a format much different from the synchronous online format commonly used in the latter part of the decade. Therefore, we did not include any articles published prior to 2010 in this study (IC5). We focused on papers that referred to engineering students or programs (or STEM research that included engineering) (IC2) from four-year colleges or universities or bachelor’s degree programs (IC3). Therefore, we excluded graduate studies, professional training programs, pre-college modules, and two plus two transfer programs. We focused on formal, online education programs (IC4) and excluded hybrid, flipped, or blended learning, massive online open courses (MOOCs), mobile learning, and learning outside of the classroom. We included documents that were published in scholarly, peer-reviewed journals or conference articles (IC6). We did not exclude articles nor evaluate them based on their research designs because research quality is not necessarily a criteria for scoping reviews.

Search Strategy

Our search strategy included filtering for terms in the title and abstract of articles. We began with Strayhorn’s [6], [7] description of sense of belonging and added related terms from our instructional experience and the relevant literature.

A search was conducted in Engineering Village on March 6, 2021 using the following strategy. We conducted a Subject/Title/Abstract search in all four of Engineering Village’s databases: Compendex, Inspec, NTIS, and Knovel. The search was limited to 2010-2020 for the year of publication, the English language, autostemming was turned off, and document type was limited to conference articles and journal articles. Accordingly, our search strings were as follows:

“Sense of belonging” or \$belong or “sense of community” or “community building” or \$engag
AND "online education" or "online learning" or "distance education" or "distance learning" or “e-learning” or “virtual learning” or “remote learning”
AND engineering
AND college or university or undergraduate

This query resulted in 483 records. Prioritizing full text and Compendex, 42 duplicates were removed, resulting in 441 articles (409 Compendex and 32 Inspec).

An abstract search was conducted in Education Research Complete from EBSCOhost on March 6, 2021 using the following search strategy.

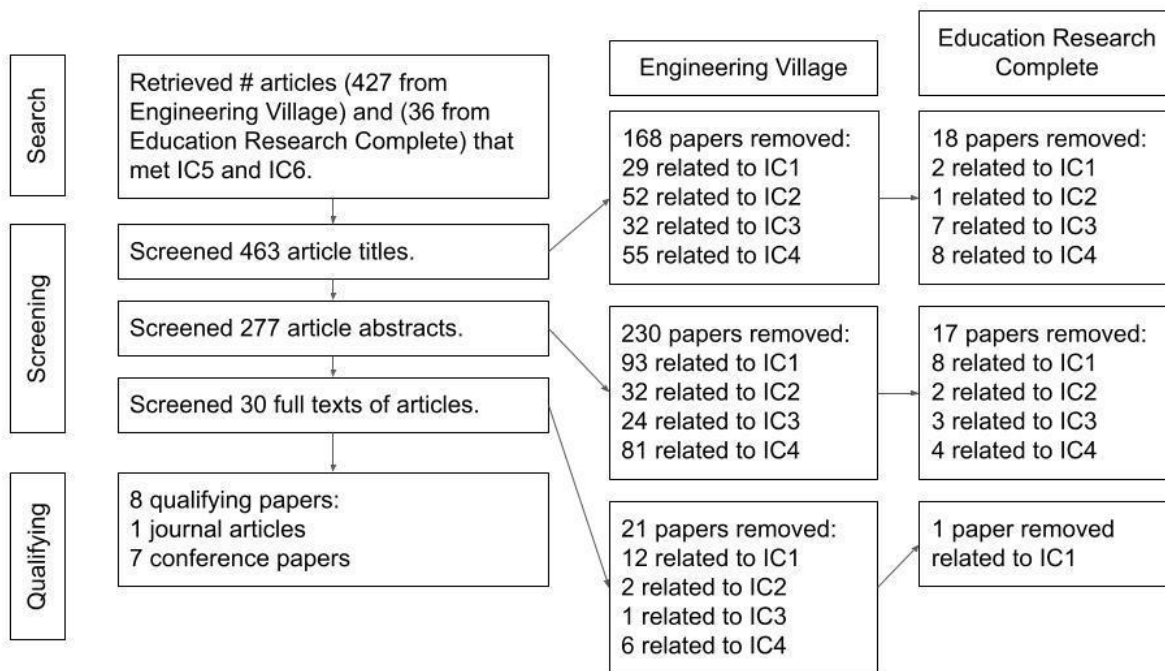
“Sense of belonging” or belong* or community or engagement
AND "online education" or "online learning" or "distance education" or "distance learning" or “e-learning” or “virtual learning” or “remote learning”
AND engineering
AND college or university or undergraduate

Similar to the Engineering Village search, we used Boolean/Phrase, publication date 2010-2020, and limited our search to the English language and Academic Journal and Conference Paper publication types. This procedure returned 36 results. Seventeen duplicated articles appeared in both searches and one copy was removed.

Selection Process

Figure 1 contains a graphical representation of our iterative search and selection processes. Exact duplicates were removed from the results, which resulted in 463 articles. Through a screening of titles, articles were removed that did not meet the inclusion criteria. For example, studies related to graduate education, subjects other than engineering, and corporate training programs were removed. This resulted in 277 remaining articles. The abstracts were then screened using the inclusion criteria, which left 30 articles remaining to review the full text. Eight qualifying articles remained after reviewing the full text.

Figure 1. Graphical representation of search process



Note: Figure adapted from Denton and Borrego [18].

Data Analysis

Full-text articles were distributed among three researchers, who each independently reviewed the full text and captured the article's author(s), year of publication, country of study, year(s) of study, population and sample, sample size, methods, theoretical or conceptual framework, relationship to "sense of belonging", and key findings. Each researcher made a decision to

include or exclude the article based on the inclusion criteria. Studies were not excluded or examined for methodological quality.

Researchers' Positionality

We are three researchers at two public, four-year universities. One researcher identifies as a White, cisgender woman who is a postdoctoral associate with a background in higher education and student affairs who has previously taught undergraduate courses in a face-to-face modality and small graduate courses in face-to-face and online synchronous environments. She was introduced to the sense of belonging framework through a keynote by Dr. Terrel Strayhorn and hopes to create affirming and inclusive classroom environments for all students, including students of color. One researcher identifies as a White, cisgender woman, and is a professor in engineering education as well as a center director. She has a background in social sciences and humanities. One researcher identifies as a White, cisgender man who is a postdoctoral fellow in engineering education research, and trained as a high school mathematics teacher and electrical engineer. The third researcher was teaching a large class during the shift to distance learning and struggled to translate the techniques he learned for in-person instruction. Accordingly, by participating in this research he hoped to gain a more comprehensive understanding of how to foster a sense of belonging in his classroom in addition to helping synthesize these findings for the broader community.

Findings

After applying our exclusion criteria, eight papers remained to be analyzed. All of the papers were published between 2011-2019. One paper was a journal article published in the *International Journal of Technology Enhanced Learning* and seven were conference papers: six prepared for the American Society for Engineering Education annual conference and one prepared for the International Conference on Industrial Engineering and Applications. Seven studies took place in the United States and one took place in Ecuador. The online undergraduate courses included mechanical engineering, systems engineering, ethical decision-making in engineering and technology, technology project management, and computer engineering.

Sample sizes ranged from 25-49 students. The methods employed in the eligible papers included structural equation modeling and social network analysis, non-experimental quantitative design with multivariate and correlational analysis, online surveys, case studies, and participant observation. Only one study [20] used a conceptual framework, the Community of Inquiry Model. Concepts related to sense of belonging studied included: a) pedagogies of engagement in online education, b) instructor interaction during and outside of class, c) peer interaction, d) student engagement and motivation, e) relationship between sense of belonging and digital competence, f) online engagement and gender, g) instructor and peer connectedness, and h) interaction with avatars, peers, and instructors in virtual worlds.

Our research question was: *In what ways has scholarship addressed potential interrelationships between sense of belonging; diversity, equity, and inclusion; and online undergraduate engineering education?* Our focused questions were: a) How is the conceptual framework of 'sense of belonging' addressed in research studies?, b) What pedagogical methods and practices

are used to promote a sense of belonging?, and c) What pedagogical methods and practices are used to promote diversity, equity, and inclusion?

Our scoping review found little scholarship studying the intersections of sense of belonging, online education, and undergraduate engineering education. We did not find any studies that used specific pedagogical methods to promote a sense of belonging or diversity, equity, and inclusion. The following five studies came the closest to our areas of interest and touched upon peer interaction, peer-instructor interaction, and feelings of connectedness.

Fatehiboroujeni et al. [21] examined student engagement and motivation in an online mechanical engineering course with an online lab on Strength of Materials. They found only 20% of students reported engaging with the instructor or teaching assistant often and approximately 18% reporting engaging with the instructor or teaching assistant very often. However, they also found that “nearly 50 percent of students interact with each other by seeking help from their peers to discuss and explain material to each other often or very often” (p. 8). Students found the discussion forum on Piazza least helpful; more than 70% of students never engaged with the online discussion board.

Rutz and Ehrlich [20] examined student responses to text-based and audio-based feedback over two semesters of an online engineering course. Delivering audio feedback took instructors twice as much time to prepare as text feedback. Although 66% of students agreed or strongly agreed that text-based comments made them feel more involved in the course, 92% of students agreed or strongly agreed that audio feedback made them feel more involved in the course than text-based feedback. Students perceived audio feedback as “personal and indicated a greater degree of concern from the instructor” (p. 11).

Little-Wiles et al. [22] surveyed two sections of 46 students in an ethical decision-making engineering and technology online course at Indiana University-Purdue University Indianapolis (IUPUI) that used synchronous chats. They found that 20% of students felt more connected to classmates in their online course environment than a face-to-face course, with 32% feeling less connected and 48% feeling the same connectedness. They also found that 20% of students felt more connected to the instructor in the online format than a face-to-face format, 20% felt less connected, and 59% felt the same connectedness. Finally, they found a small student preference for instructor-led synchronous chats over rotating peer-led synchronous chats.

Lesko [23] explored the use of avatars and virtual environments in a technology project management course with 47 learners in the online section. Findings about whether or not the presence of avatars enhanced group communication and interaction were mixed: 9 students agreed or strongly agreed, 23 were undecided, and 10 students disagreed or strongly disagreed.

Avanzato [24] also explored the use of a virtual environment in an online sophomore-level computer engineering course in digital design at the Penn State Abington campus, required for computer science, electrical engineering, and computer engineering students. The instructor, who previously taught the course in face-to-face and asynchronous online modalities, observed that the virtual environment “collaboration tool greatly increased the student-to-faculty and

student-to-student communication and engagement, as compared to prior experiences” (p. 12). Eleven of fourteen survey respondents rated the virtual world technology as excellent or good for supporting student communication and collaboration in the online course. One student explained, “You felt more a part of the course than your ‘normal’ online class, better interaction between students and the teacher....” (p. 12).

Discussion and Implications

The qualifying studies we identified, especially several of the studies we omitted by applying our exclusion criteria, were only tangentially related to sense of belonging, with most focusing on instructor and peer interaction, feelings of connectedness, and communication and engagement within the online course environment. Although the pedagogical methods and practices used in the studies identified by our scoping review were not examined in light of diversity, equity, and inclusion, they do have modest connections to sense of belonging through peer interaction and student-instructor interaction. For example, frequency of peer interaction has been positively associated with a sense of belonging for students of color in STEM [7].

Student-to-student interaction and student-instructor interaction are two common predictors of sense of belonging. Our review identified student-to-student interaction in the context of seeking help from and explaining material to peers [21]. Online instructors can establish a teaching presence by developing “activities that promote interaction and socialization” and “facilitate learner dialogue” (p. 7) [11].

Online classes using synchronous chats resulted in mixed student feelings of “connectedness” as compared to face-to-face classes [22], but there was a small preference for instructor-led synchronous chats over rotating peer-led synchronous chats. Pilcher [13] found that “students with strong sense of community showed greater levels of learning and satisfaction” (p. 10) in online classrooms.

Our findings related to peer and instructor interaction and sense of community align with good practices emerging during the pandemic’s shift to online learning, which include using dynamic, engaging, student-focused approaches to teaching and learning such as “problem-based learning, self-learning, peer learning, team learning, the flipped classroom, and the use of simulations and games, all of which can be used separately or in combination” (p. 9) [4].

Student-instructor interaction was addressed by identifying student preference for audio versus text instructor feedback [20]. Timely instructor feedback has been identified as one of two of the most valuable activities for online instructors to establish instructor presence [13]. This finding builds on good practices for aligning learning and assessment identified during the pandemic, “the need to fully align learning-assessment procedures and criteria with online curricular and pedagogical practices” (p. 9) [4]. Instructors can provide timely audio feedback, as one way to align assessment and students’ need for instructor interaction.

Although our scoping review of the ways scholarship has addressed interrelationships between sense of belonging; online undergraduate engineering education; and diversity, equity, and inclusion did not yield any results at the intersection of the topics, it did offer implications for

practice and opportunities for future research. In particular, it demonstrates a substantial gap in our knowledge on these topics. Online engineering classes are often large and leave room for students to disengage, putting them at risk of attrition. Given the research agenda for the engineering education discipline highlights diversity and inclusion scholarship as one of its pillars [25], sense of belonging as a conceptual framework is ripe for scholarship of teaching and learning in engineering education, especially online courses. Sense of belonging is especially pertinent for students from racially marginalized backgrounds and women and gender minority students, groups traditionally underrepresented in engineering education. With little improvements in the recruitment and retention of racially minoritized and women students in engineering education, sense of belonging is an under-examined possible contributing factor for low persistence rates in the discipline. Engineering faculty may need to look outside the discipline of engineering education, or even STEM, for theoretical frameworks such as sense of belonging and applications to engineering education.

In terms of future research directions, a few strands of inquiry were found in our review. For example, Lesko [23] found mixed responses to whether or not the presence of avatars in virtual environments enhanced group communication and interaction, whereas Avanzato [24] felt the use of a virtual environment increased peer and instructor-student communication and engagement. The use of avatars and virtual environments in online engineering classes may offer faculty additional opportunities to improve student engagement, connection, and peer and instructor interaction.

Limitations

The scoping review process had several limitations, most of which relate to our goal of identifying engineering education research within a narrowly scoped lens. Firstly, we chose to focus on peer-reviewed, scholarly journal articles and conference articles, and in doing so may have missed research published in book chapters, for example, as well as emerging knowledge published in blogs, news articles, and other informal scholarship outlets. Additionally, our initial search was limited to two databases: Engineering Village and Education Research Complete, which does not cover all possible articles.

Although the sense of belonging framework has been well established in school and college literature, it has not often been applied in large, technical academic disciplines such as engineering education. Therefore, while some faculty may be doing research on this topic, they may not use the same keywords that we did, drawing from the higher education and student affairs literature (such as belonging, engagement, and connectedness). We found engagement to be a key term that was misleading in the online education environment, as it was often associated with time spent in a learning management system, which did not fit with our definition of sense of belonging.

In searching for literature at the intersection of online engineering education and sense of belonging, we may have missed research and practices related to belonging and face-to-face engineering instruction that may be applicable to online learning environments. This might be another area for future research. Moreover, some literature might have been excluded because they were not at the specific intersection of keywords we were interested in, such as engineering

AND sense of belonging. These pieces could have provided additional insights as well that were not specific to online education.

Finally, because of the emergent nature of the formal literature on the COVID-19 pandemic, we acknowledge that a considerable body of work is under review or slated to be published that would have fit the inclusion criteria we established. Moreover, several informal bodies of work have been generated on blogs, in podcasts, and other publications that were excluded because of IC6. These pieces could also be included in another iteration of this review to expand the scope of possible publications to popular media, which have broader recommendations for online teaching that have been vetted to some formal capacity through the time teaching remotely.

Conclusion

Drawing from hierarchy of needs [8] and sense of belonging frameworks [6], [7] and lessons learned from the first six months of the pandemic [4], students will not learn their best until their physical (including health, financial, and technological) and socioemotional needs are met. Faculty and peer relationships and online course environments can be part of a comprehensive strategy to support vulnerable students and enable them to thrive in online engineering education environments.

Although prevalent in higher education literature, sense of belonging remains largely unexplored in online undergraduate engineering classes and underrepresented students within those classes. In order for students to have an optimum learning experience in an online environment, especially students with marginalized social identities, faculty must pay special attention to creating a sense of belonging. Therefore, we contend this literature review will be a starting place for engineering faculty and researchers as online education becomes a more standard feature of the curriculum, and it will serve as a baseline for efforts in this area before the 2020 year of the pandemic when this issue became critically foregrounded.

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