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REVIEW ARTICLE

Engineering graduate students' mental health: A scoping literature review

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Abstract

Background: Mental health issues reported among college-aged individuals have increased. Prevalence of these issues has an established impact on students' personal, professional, and academic outcomes. Graduate students experience unique stressors that impact their mental health. In particular, engineering graduate students have lower help-seeking tendencies, which can impact the severity and length of their mental health problems.

Purpose: We investigate the literature concerning engineering graduate students' mental health, focusing on academic outcomes, mental health measures, and mental health findings, to highlight gaps in current literature and the need for further research.

Scope/Method: Five research databases, EBSCO: CINAHL, EBSCO: PsycINFO, ProQuest: ERIC, PubMed, and Scopus, were searched in a scoping literature review. Inclusion and exclusion criteria were applied during the screening process. Peer-reviewed publications (i.e., articles and conference papers) were identified and coded for study focus, keywords, participants and institution(s), journal discipline, study type, methods used, and work referenced, in addition to academic outcomes, mental health measures, and mental health findings.

Results: Nineteen of the 4,826 unique studies identified were included in the review. Ten academic outcomes and 13 mental health measures were discussed. Mental health findings were grouped into five themes: social support and sense of belonging; student–advisor relationship; cultural barriers faced by international students; gender and racial stereotypes; and generalized findings.

Conclusions: Research on engineering graduate students' mental health is limited. Given that mental health has direct ties to students' well-being and ultimately their success, engineering education researchers should focus on studying students' experiences, sharing these findings, and communicating best practices for all stakeholders.

Disclaimer: This article discusses mental health, and as a part of that, suicide. Please engage with this material as much or little as you may need. In addition, this paper cannot and does not constitute medical advice in any shape or form. The information presented in this article does not substitute for the knowledge, skill, and judgement of qualified health care professionals. Some mental health resources can be found at the following links: https://www.mentalhealth.gov/, https://www.nami.org and https://www.nami.org/Find-Support/NAMI-HelpLine/Top-25-HelpLine-Resources.

KEYWORDS
engineering, graduate, higher education, mental health, scoping literature review

1 | INTRODUCTION

A growing national mental health crisis underway for over a decade has left higher education institutions struggling to meet students' mental health needs (LeViness et al., 2017). A recent study of US college students showed a rise in student-reported suicidal ideation (5.8%–10.8%), mental health service utilization (18.7%–33.8%), and diagnosed mental health conditions (21.9%–35.5%) from 2007 to 2017 (Lipson, Lattie, & Eisenberg, 2019). Furthermore, a recent survey showed that graduate students were six times as likely to suffer from depression and anxiety as non-students their age (Evans et al., 2018). Given there were over three million young adults enrolled in postbaccalaureate higher education in 2019, it is critical to understand students' mental health problems in higher education so that all stakeholders can work to alleviate emotional burdens and promote positive mental health experiences (National Center for Education Statistics, 2019).

The purpose of this paper is to identify and synthesize the current literature examining US engineering graduate students' mental health. In this work, we perform a scoping literature review (ScLR) of five databases. The primary research question motivating this work is *what is the current landscape of literature about engineering graduate students' mental health?* First, the following section defines mental health for this study. Next, we discuss the human, academic, and economic impacts of mental health problems, as well as the impact of the COVID-19 pandemic. Then, we focus on the research surrounding graduate and engineering students, respectively. After this, we discuss the methods used to conduct this review before presenting our results. Findings illustrate the different research designs, motivations, use of existing literature, and topics studied with regard to this focus. Furthermore, we shed light on the fragmented state of this work and the need to establish a shared vocabulary among scholars in this area. Finally, we provide suggestions for future research on engineering graduate students' mental health.

2 | DEFINING MENTAL HEALTH FOR THIS STUDY

This study focuses on mental health, which we defined as anything related to a person's emotional or psychological well-being (i.e., their mental and emotional state). The term "mental health" is often used alongside and/or interchangeably with a broader meaning of "well-being." Well-being has been more broadly defined as a "holistic concept referring to both physical and mental health ... [including] personal safety and security, emotional support and connection, mechanisms to cope with stressors, and access to services" (National Academies of Science, Engineering, and Medicine [NASEM], 2021, p. 3). Although related, the scope of this paper focuses on mental health.

3 | THE HARM CAUSED BY PERVASIVE MENTAL HEALTH PROBLEMS

3.1 | Human impact

Mental health problems affect everyone on an individual, familial, community, and societal level. Death by suicide is and has been one of the top leading causes of death among college-aged students, second only to the rate of accidental injuries (Turner et al., 2013). In addition, self-reported mental health concerns have risen in the past decade, including the almost doubling of reported suicidal ideation (Lipson, Lattie, & Eisenberg, 2019). A recent report on mental health, substance use, and well-being in higher education has highlighted concerns that the COVID-19 pandemic, the rise in unemployment and instability in the US economy, and increased awareness of anti-Blackness and racism has coincided with increased self-reported anxiety and depression (NASEM, 2021). This collective evidence calls for concerted efforts to address mental health.

Individuals with mental health problems (e.g., anxiety, depression, etc.) can have a lowered satisfaction with life and increased severity of mental health problems (Fergusson et al., 2015; Jenkins et al., 2020). Furthermore, individuals with two or more mental health problems are likely to experience greater quality of life impairment (Eisenberg, Golberstein, &

Hunt, 2009; Jenkins et al., 2020). This is concerning as mood, anxiety, and substance use disorders are highly comorbid among young adults, with roughly one-third of adults ages 18–29 meeting the criteria for two or more disorders (Tanner, 2015). Mental health disorders also coincide within families. Having a family member with a mental health illness increases the risk of mental health problems, and caregivers for people with mental health disorders suffer particularly significant mental and physical impacts (i.e., financial costs, social exclusion, isolation, stress, poor health; Ennis & Bunting, 2013).

Students with mental health problems are often concerned with the stigma surrounding their diagnoses, given its potentially negative impact on their lived experiences. Recent research has demonstrated that students believe others would have a negative opinion of someone receiving mental health care and that students with disabilities often confront pushback and hostility when seeking academic accommodations (The Healthy Minds Network [HMN], 2021; Zongrone et al., 2021). Students have disclosed experiences encountering people with ableist mindsets when requesting academic accommodations from faculty and staff, such as being told they are looking for an unfair advantage or a means to "cheat" the system (Zongrone et al., 2021). This fear of being perceived and treated differently by others in academia can hamper students' help-seeking behaviors, which, in turn can, prevent them from accessing tools and resources that help them persist both personally and academically (Eisenberg, Downs, et al., 2009; Zongrone et al., 2021).

3.2 | Academic impact

The short and long-term effects of mental health problems on students' academic performance can have dire impacts on student outcomes. Depression causes significant cognitive impairment, affecting executive function, memory, and attention, not confined to depressive episodes (Rock et al., 2014). Even mild forms of depression predict lower cognitive function that can worsen with time (Dotson et al., 2008; Laukka et al., 2018). Mental health problems have a lasting negative impact on student outcomes, including social connectedness, academic performance and retention, and future economic productivity (Lipson et al., 2016). Depression, anxiety, and eating disorders all strongly predict lower grade point averages, with comorbidity of depression and anxiety predicting stronger impacts (Eisenberg, Golberstein, & Hunt, 2009). A study conducted in the United Kingdom found a correlation between depression and lower performance on exams (Andrews & Wilding, 2004). Mental health problems generally predict students' being unhappy with their academic careers, wavering intentions to persist, lower confidence in degree completion, and attrition (Lipson & Eisenberg, 2018; National Alliance on Mental Illness [NAMI], 2012). Reported mental health problems double students' risk of leaving school prior to degree completion (NASEM, 2021), perhaps because of a higher risk of other negative academic outcomes.

3.3 | Economic impact

Mental health issues can also impair students from engaging in the workforce and thus impact global competitiveness. Untreated mental health issues can increase how long individuals experience mental health problems and the probability of relapse (Hunt & Eisenberg, 2010; Kessler et al., 2007). Unfortunately, delaying treatment after onset of a mental disorder for 10 years or more is common (Kessler et al., 2007). Thus, students who experienced onset in college are likely still living with untreated mental health issues when or if they enter the workforce. Mental health problems can negatively impact students' intentions to persist and obtain their degrees, adding to an existing shortage of skilled individuals to perform science, technology, engineering, and mathematics (STEM) jobs, dubbed the STEM Crisis (Lipson & Eisenberg, 2018; NAMI, 2012; White House Office of Science and Technology Policy, 2014).

Mental health problems can also have detrimental costs on students' future abilities and productivity. Mental health is the third costliest disease for employers in the United States, averaging a cost of $348/employee annually (Davlasheridze et al., 2018). Over half of the reported approximately 550 million workdays lost annually due to absenteeism were stress-related (Danna & Griffin, 1999). With the rise in mental health problems resulting from the COVID-19 pandemic, the prevalence of mental health problems is likely to increase in the coming years.

3.4 | Impact of COVID-19

The COVID-19 pandemic has highlighted disparities and inequities that have plagued student mental health. A survey of US students found that 60% reported that the pandemic had made it increasingly difficult to access mental health care

(Healthy Minds Network & American College Health Association, 2020). In a UK survey, 80% of respondents reported that their mental health had worsened due to the pandemic, and over 30% of those who were accessing mental health services in the 3 months prior to the crisis and still needed it, no longer had access (Young Minds, 2020). Currently, college counseling centers cannot meet the demand for students' mental health needs (LeViness et al., 2017). Given the shortage of mental health professionals in the United States (Thomas et al., 2009) and globally (Kakuma et al., 2011), work is needed to ensure today's college students have support in addition to traditional counseling services.

4 | GRADUATE STUDENTS ARE OVERLOOKED

Mental health problems significantly impact research productivity (Danna & Griffin, 1999). They can interfere with students' abilities to fulfill their graduate degree requirements and their intentions to persist. Over half of doctoral students do not complete their degree (Sowell, 2010). Surveys have demonstrated that stress, anxiety, exhaustion, and/or a lack of interest factor into these decisions (Anttila et al., 2015; Schmidt & Hansson, 2018). A recent study focusing on engineering graduate students' attrition found that intentions to persist are often impacted by more than one mental health concern (Berdanier et al., 2020); that is, the many concerns and questions that can impact students' decisions to leave engineering are often layered and interconnected (i.e., advisor role and relationship, support network, quality of life and work, cost, perception by others, goals; Berdanier et al., 2020). Research has also demonstrated that doctoral degree programs have attributes that make students want to leave. A 2017 study found that PhD students consistently reported a higher severity of mental health problems, including feeling worthless, unhappy, and depressed, as compared to peers in comparable spaces (i.e., students not in PhD programs and individuals in the general population who already have advanced degrees; Levecque et al., 2017). Likewise, a 2018 study showed that graduate students from a variety of fields (biological/physical science, engineering, humanities/social science, and others) were six times as likely to experience depression and anxiety as their same-age peers not in graduate school (Evans et al., 2018).

It is fair to ask, then, *why are graduate students' mental health problems routinely overlooked?* Recommendations for campus mental health services have stressed the importance of services being "of high quality and tailored to the special needs of college students" (Mowbray et al., 2006, p. 234). Yet research examining graduate students' mental health experiences is minimal, disorganized, and fragmented (Hish et al., 2019). For example, a study of biomedical doctoral students found that although they are a population at risk of experiencing severe mental health problems, little work has been done to understand these concerns (Tsai & Muindi, 2016). In addition, studies of mental health experiences generally do not distinguish between undergraduate and graduate students (Hefner & Eisenberg, 2009; Hunt & Eisenberg, 2010; Lipson et al., 2016; Lipson & Eisenberg, 2018; Wilson et al., 2010; Wyatt & Oswalt, 2013). These studies overlook differences across academic levels, such as varying academic and social demands (e.g., focusing on research versus courses, communicating work, goals, and career aspirations as opposed to hobbies, interests, and social activities; Wyatt & Oswalt, 2013).

5 | ENGINEERING STUDENTS DO NOT ASK FOR HELP

In any discipline, students must constantly balance academic demands, personal obligations, professional aspirations, and overall health and well-being. This balancing act can impact students' willingness to seek help. In addition, cultural stigma, personal beliefs, and systematic barriers (e.g., high health care costs, lower socioeconomic status, and insufficient health insurance coverage) can prevent students experiencing mental health problems from seeking help (Eisenberg et al., 2007). However, delays in seeking help can increase the length and severity of problems and decrease the effectiveness of treatment (Hunt & Eisenberg, 2010; Lipson et al., 2016). Engineering students specifically are less likely to seek help than, for example, students in the humanities or arts, while exhibiting higher stress levels and lower rates of engaging in physical activity that might help offset stress (Hyun et al., 2007; Lipson et al., 2016). This may correlate to gendered differences; women are underrepresented in engineering and are significantly more likely to consider seeking help or utilizing resources (Hyun et al., 2007).

6 | ROLE OF ENGINEERING EDUCATION RESEARCHERS IN THIS WORK

For studying and understanding the mental health climate surrounding engineering graduate students, researchers must be able to navigate and understand all aspects of engineering culture to help others understand the impact it can

have on students' mental health. Engineering education researchers are uniquely situated to study engineering graduate students as they often have knowledge about navigating the culture of engineering. First, many researchers serve as advisors to graduate students. They are familiar with the different norms within disciplines and degree programs, and therefore, their varying work cultures and perspectives on mental health. Understanding norms, both explicit and implicit (Villanueva, Gelles, di Stefano, et al., 2018; Villanueva, Gelles, Youmans, & di Stefano, 2018), gives engineering education researchers a perspective on the environmental factors that may be at play (e.g., mentorship styles or cohort sizes). This can provide insight into the underlying relationships and mechanisms that affect engineering graduate students' mental health.

Also, as most engineering education researchers are familiar with quantitative, qualitative, and mixed methods research, they are equipped to connect their findings with relevant academic outcomes. In addition, engineering education researchers can develop and test interventions for classrooms, faculty development, academic support systems, and more to combat cultural barriers to positive mental health practices. Finally, their research can provide evidence-based practices that will directly benefit engineering graduate students' mental health for all stakeholders. Such research will require an understanding of the current landscape of literature about engineering graduate students' mental health.

7 | METHODS

As previously mentioned, in this work, we identify and synthesize the current literature examining US engineering graduate students' mental health through performing a scoping literature review. This study follows pre-established methods that are used to conduct ScLRs, (Arksey & O'Malley, 2005; Grant & Booth, 2011; Samnani et al., 2017), as discussed in our previously published conference proceedings (Bork et al., 2019). There are many similarities between ScLRs and systematic literature reviews. Both include searches of completeness determined by time and scope restraints; neither have formal quality assessments, and analysis includes characterizations of the quantity of literature, quality of literature, study design, and key features (Grant & Booth, 2011). A major difference, however, is that a systematic review includes appraisal mechanisms to assess and set a minimum quality for studies included in the review, whereas ScLRs do not. ScLRs are performed to learn the extent of research that has been conducted in a specific field, typically with broader research questions guiding the study, with the main objective of synthesizing and reporting on existing literature (Grant & Booth, 2011).

This ScLR had five stages, as detailed in Table 1 (Arksey & O'Malley, 2005). Table 1 features details about each stage, including its main objectives and outcomes. A librarian who specializes in literature review searches provided guidance for this review by helping to refine the research questions and select databases, aiding the development of the search protocol, and providing resources to guide the entire process. We describe each stage in the sections that follow.

7.1 | Stage 1: Identify the research question(s)

In this stage, the research question was formed: *What is the current landscape of literature about engineering graduate students' mental health?* This question helps situate the context of the study, as evidenced in the formation of the study's three central inclusion criteria: the study must (1) discuss graduate students, (2) include engineering students, and (3)

TABLE 1 The five stages of an ScLR (generated from Arksey & O'Malley, 2005)

Stage	Objective	Outcomes
1: Identify the research question(s)	Determine the scope of the project and focus on search	Inclusion and exclusion criteria
2: Identify relevant studies	Determine relevant sources of literature	References for study
3: Study selection	Define the screening process	Eligible references
4: Charting the data	Coding the literature and recording vital information	Literature data for analysis
5: Summarize and report results	Condense and organize all information collected into a coherent report	Identify current literature trends and potential research gaps

Abbreviation: ScLR, scoping literature review.

discuss the mental health of these students. Graduate students were defined as any student working toward a master's or doctoral degree, with mental health being defined as anything related to a person's emotional or psychological well-being. The working definitions and example search terms are detailed in Table 2. Additional inclusion/exclusion criteria were used to determine if studies should be included in the review. Studies were excluded if they did not come from a peer-reviewed source, were not written in English, or did not focus on students studying in the United States. The only restriction on the publication date was the date of the second and last search (August 6, 2019). Table 2 includes the working definitions and how these criteria were implemented in the review process.

7.2 | Stage 2: Identify relevant studies

Five databases were used to search for articles: EBSCO: CINAHL, EBSCO: PsycINFO, ProQuest: ERIC, PubMed, and Scopus. These databases were selected with guidance from a librarian.

Collectively, they cover a breadth of areas that are relevant to the research question, including allied health literature, biomedical science, behavioral science, education, health sciences, life sciences, mental health, nursing, physical sciences, psychology, public health, and social sciences. Search protocols were developed using the three central inclusion criteria, yielding the following general search block for all fields: ("engineering") AND ("doctoral" OR "master") AND ("student") AND ("mental health" OR "well-being" OR "depression" OR "anxiety"). Other example search terms are featured in Table 2, with the full search terms used for each database available online in Supporting Information S1. Guided by the inclusion and exclusion criteria detailed in Table 2, the first author performed the database searches on two separate occasions. These searches resulted in the 4826 unique articles that formed the basis for the screening and selection process for this review. The following sections detail the screening and selection process that followed. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram illustrated in Figure 1 provides a visual overview of this review's complete search and screening processes.

7.3 | Stage 3: Study selection

For this stage, we created screening questions to enforce the inclusion and exclusion criteria. The screening questions for each step are featured in Table 3. The selection process had four steps: title screening, abstract screening, full-text

TABLE 2 Inclusion and exclusion criteria used to guide the ScLR

The three central inclusion criteria		
Inclusion criteria	**Working definition**	**Example search terms**
Graduate students	Any student working toward a master's or doctoral degree (e.g., PhD, MS)	Graduate education, doctoral, masters, PhD, and student, candidate
Engineering	Any discipline included in engineering	Engineering
Mental health	Anything related to a person's emotional or psychological well-being	Mental health, depression, anxiety, wellness, quality of life
Additional inclusion/exclusion criteria		
Inclusion criteria	**Working definition**	**How implemented**
Peer-reviewed	Article or conference paper part of a peer-review process for publication	Verifying published with the peer-review process (e.g., not blogs or gray literature)
Written in English	The publication needed to be available in the English language	Database search restriction
US students	Any student studying in the United States	Study participants needed to include US students; screening stages
No date range	Any date range on the publication	All publications until the date of the literature search included (March 12, 2019, and August 6, 2019)

Abbreviation: ScLR, scoping literature review.

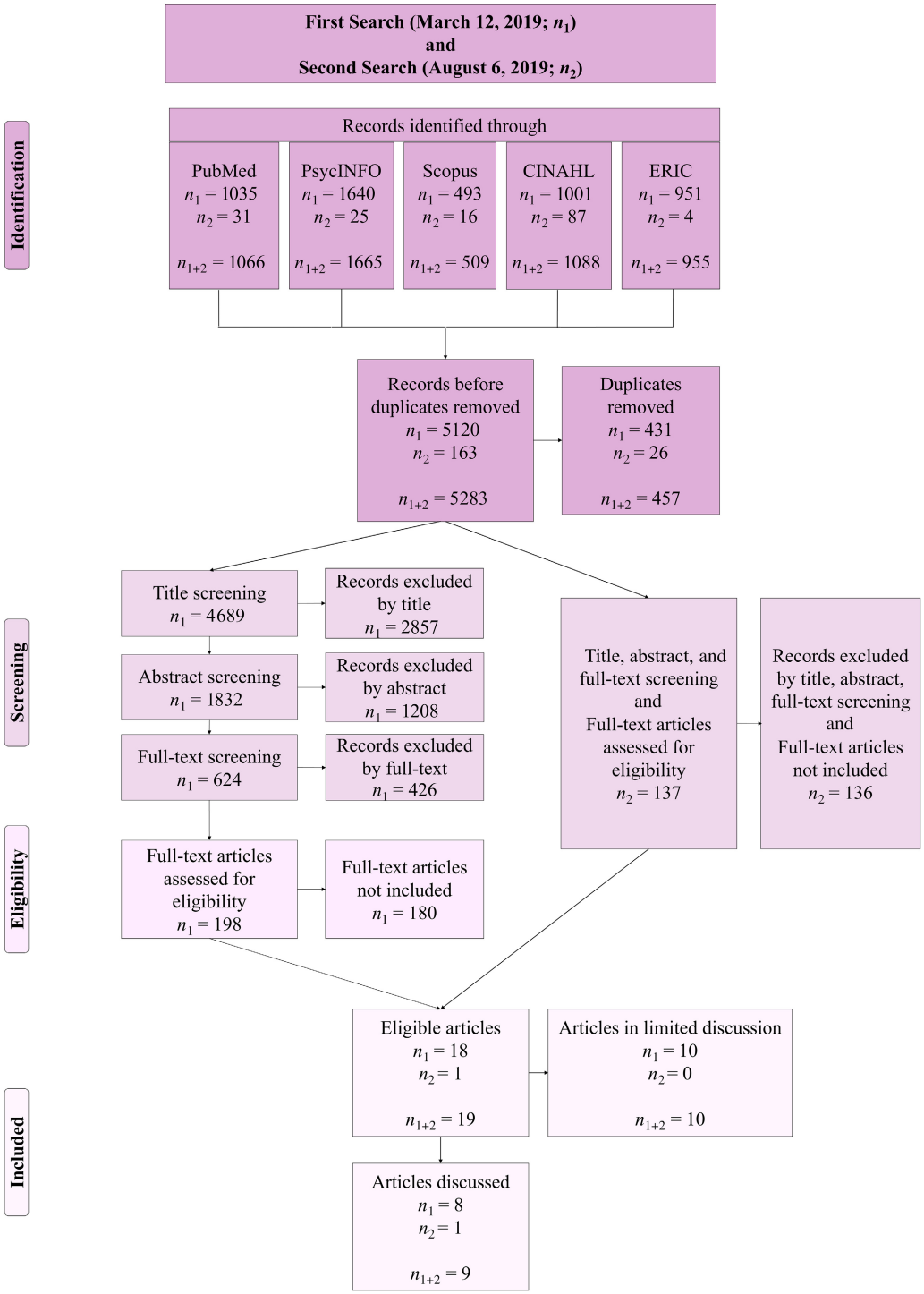

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram demonstrating the search and separate screening process of studies to be included in this review by detailing the cumulative results from the first search conducted on March 12, 2019 (n_1), and the second search conducted on August 6, 2019 (n_2). [Color figure can be viewed at wileyonlinelibrary.com]

screening, and full-text eligibility. The first three steps were exclusionary screening stages. They were intended to exclude any study that clearly did not fit one or more of the criteria. This also meant that unless a study clearly contrasted inclusion criteria, it would be included. The last step, full-text eligibility, was an inclusionary process. This meant that the screening questions were made dichotomous, and a "yes" was needed to include the study; that is, the studies needed to clearly meet the inclusion criteria to be included. The researchers ran the search protocol twice; first on March 1, 2019, and second on August 6, 2019.

TABLE 3 Screening questions used in the ScLR to enact inclusion/exclusion criteria

Step	Screening question(s)	Response for inclusion	Reviewers' agreement for March search	Reviewers' agreement for August search
Title screening	Is the title relevant?	Yes, not sure	One and two screened independently, discrepancies discussed; 79% agreement rate	One and two completed all stages of screening independently; compared final included papers and discussed any disagreement
Abstract screening	Is this abstract focused on students in the United States?	Yes, not sure	One and two screened training sets of 10 and 20 studies independently until 80% agreement reached; three rounds required (50 studies in total)	
	Does this abstract include only those in clinical practices (medical training, nursing, veterinarian, etc.)?	No, not sure		
	Does the abstract discuss mental health?	Yes, not sure		
	Are graduate students a major focus of this study?	Yes, not sure		
	Are Engineering students a major focus of this study?	Yes, not sure		
Full-text screening	Is this study focused on students in the United States?	Yes, not sure	One, two, and three screened training sets of 5 and 10 studies independently until 100% agreement reached; four rounds required (35 studies in total)	
	Does this study include those in clinical practices (medical training, nursing, veterinarian, etc.)?	No, not sure		
	Does the paper discuss mental health?	Yes, not sure		
	Are graduate students a major focus of this study?	Yes, not sure		
	Are Engineering students a major focus of this study?	Yes, not sure		
	Where was this article published?	Any peer-reviewed publication		
Full-text eligibility	Is this study focused on students in the United States?	Yes	Two and three reviewed independently, bringing in one on any discrepancies; all final papers reviewed together for 100% agreement	
	What mental health terms are used?	Any non-chronic ailment		
	What degree programs are the students a part of?	Masters, doctoral, graduate		
	What disciplines are explicitly stated?	engineering		
	Where was this article published?	Any journal publication		
	Are engineering graduate students included in the article?	Any response		

Abbreviation: ScLR, scoping literature review.

For data collection, title screening was completed using the systematic literature review software DistillerSR due to the volume of titles and interfacing provided (Evidence Partners, 2022). The reviewers used the software to screen the study titles independently; the responses were recorded and downloaded to a Microsoft Excel sheet, which was used for comparisons. This sheet was used to gather the titles for the abstract screening, where the same process for data collection took place. Google Forms were used for the data collection for full-text screening, full-text eligibility, and all inter-rater reliability checks as Google Forms connects directly to Google Sheets, making for easy comparisons.

Three reviewers screened across both searches. Table 3 illustrates a summary of the process for both searches. The first researcher is the first author of this publication and was the main reviewer and lead for the project. The second and third researchers both assisted in the project, with the third researcher joining the team after the title screening stage and leaving before the August search was conducted. Although the August search was conducted by a smaller study team, there was a lower number of studies to screen, and the reviewers were able to build on their experiences from the March search. Given this, during the August search, the first and second reviewers completed the title screening, abstract screening, full-text screening, and full-text eligibility screening independently. The same process for screening the studies was followed (excluding the inter-rater reliability checks) as detailed in Table 3. However, as a result, only the aggregate data for the August search was available and presented in the screening process in Figure 1. For the sake of clarity, the following sections on title screening, abstract screening, and full-text screening only provide details for the March search, with the full-text eligibility section providing details from both.

7.3.1 | March: Title screening

The 4689 titles were screened by answering the question, *Is the title relevant? (Yes, No, Not Sure)*. The reviewers interpreted this to mean "*Does the title make a statement that directly conflicts with an inclusion item?*" The first and second reviewers independently screened all the study titles. During reviewing, any large uncertainty or discrepancy in the criteria was discussed. Once the screening was completed, the responses from the two reviewers were compared. Any discrepancy (a yes/no or yes/not sure pairing) was noted and then screened jointly by the first and second reviewers, ensuring that any uncertainty with the inclusion/exclusion criteria was clarified. The reviewers had a 79% agreement rate on the inclusion of papers to the next screening stage. From the title screening, 2857 studies were removed, lowering the number of studies from 4689 to 1832.

7.3.2 | March: Abstract screening

Five questions were used in this step. For measuring the level of agreement between the first and second reviewers, subsets of the articles in the screening stage were made into training sets. The reviewers first started by independently screening the first training set (10 studies). Responses for study inclusion were compared, with any differences in inclusion between reviewers discussed until an agreement was met and the underlying inclusion/exclusion criteria were clarified. The following training sets included 20 studies, and this process of independent screening, comparing, and discussion continued until the reviewers came to at least an 80% level of agreement (Bradley et al., 2007). This was done for two rounds, or a total of 50 studies discussed. Also, at the end of the abstract screening, both reviewers used the final 20 studies as a training set to again assess the level of agreement. Next, the first and second reviewers divided and screened the remaining abstracts, communicating as needed for clarity or assistance throughout the process. There were 1208 studies removed at this stage, reducing the number of studies from 1832 to 624.

7.3.3 | March: Full-text screening

Six questions were used at this step. Before the screening could begin, the full text of each study needed to be downloaded. The first and third reviewers matched the reference numbers of the studies that passed the abstract screening to the title and authors of each article so they could be downloaded. All three reviewers then participated in the screening process. As with the abstract screening, reviewer agreement was measured to allow for the screening to be split. All three reviewers screened, compared, and discussed the first training set, consisting of five studies. The same process followed with sets of 10 studies until all three authors agreed on the inclusionary status for the 10 studies (agreement

reached 100%). This took three sets of 10, with a total of 35 papers being discussed. After an agreement was achieved, the remaining papers were split between the three reviewers. This screening stage removed 426 studies, leaving 198.

7.3.4 | August: Title, abstract, and full-text screening

The same screening process was followed as in the March search. Although the August search was conducted by a smaller study team, there was a lower number of studies to screen, and the reviewers were able to build on their experiences from the March search. During the August search, the first and second reviewers completed the title screening, abstract screening, full-text screening, and full-text eligibility screening independently. They only checked in to discuss confusion on agreement criteria and then at the final step to discuss the papers to be included in the study (as detailed in Table 3). As a result, only the number of studies included in the review is discussed in the following section.

7.3.5 | March and August: Full-text eligibility

At this point in the review, a study could only make it to the data extraction and analysis stage if it clearly met all of the inclusion criteria, verified through the screening questions. The first five questions included in this section were used to determine eligibility. The sixth question was added to the screening because of discussions by reviewers surrounding the first full-text screening: *Are engineering graduate students included in the article? (Yes, No)*; that is, when screening, we found that engineering graduate students may be included in a study without being explicitly discussed in the results or analysis. Thus, no findings could be clearly attributed to the population of interest. The question did not affect the inclusion of the article in the study, but it is important to note if the population of interest was indeed singled out in the analysis and/or discussion.

For this final stage of the March search, the studies were split between the second and third reviewers and screened concurrently. If any level of uncertainty arose, all three reviewers would discuss it together and add clarifications to the inclusion and exclusion criteria. All three reviewers then read the final round of included studies, checking each for eligibility. The same process as the August search was used, except only the first and second reviewers were involved in the process. One common reason for the rejection of a study was a lack of clarity as to whether engineering graduate students were included in the study sample (i.e., papers with engineering students and graduate students, but no indication of overlap between the categories). From the March search, 180 studies were removed in the final stage, leaving 18 studies; only one study remained from the August search. From these 19 eligible studies across the two searches, nine studies differentiated engineering graduate students in the results.

7.4 | Stage 4: Charting the data

The main objective for this step was to collect the information of interest from each of the studies included. This was done via a coding rubric designed to extract key points of the data. The inclusion and exclusion criteria were used to operationalize the screening questions to ensure these topics were discussed. The coding rubric served to expand upon these topics and determine the degree to which they were expressed across the studies. Initially, the coding rubric was developed based on information the first author was expecting to find. One study was selected as a test paper and used to refine the coding rubric and resolve any confusion for the reviewers. An "other" category was used to provide space for anything not referenced in the coding rubric.

When developing the coding rubric, two categories became apparent: study information and mental health measures. In terms of items that could be categorized, study information included the study type, participant information, demographics (academic discipline, age, citizenship/nationality, gender/sex, parental education, living situation, relationship status, and year in program), cited work, and methodology. Two other items that were recorded in an open format included the study's goals and key findings. Mental health measures refer to the variables used in each study with regard to mental health; the items coded for were based on items found through the literature review or through the refinement of the coding rubric. Mental health variables included anxiety, coping habits, depression, emotion(s), existing mental health problems, life satisfaction, relationship(s), self-harm, suicidal ideation, stress, treatment utilization, well-being, and work-life balance. Any item that did not fit within the listed demographic categories or mental

health variables was included in an "other" category, allowing the rubric to be updated based on the content of each paper. The first reviewer coded responses to see if any patterns appeared across studies that may have been missed. Anything that was reported in more than one study was included in the results section below. Once the rubric was completed, each reviewer independently read and coded the articles. All three reviewers then discussed each article collectively, summarized the information, and checked for consistency.

7.5 | Stage 5: Summarize and report results

The final stage was to shorten and summarize the key findings from each of the 19 studies. This was done via an in-person group discussion to ensure that the information gathered was accurate. The reviewers collectively distilled each study's information into key points collectively to ensure everyone agreed with the final output. This information is reported in the results section.

7.6 | Research team positionality

The positionality of the research team is provided, given its recognized impact on how research is conducted (Hampton et al., 2021; Secules et al., 2021). The authors are located at a research-intensive, Midwestern, historically White higher education institution. The first author experienced all of her higher educational training in this type of environment, which impacted her perspective. Her experiences matriculating from the field of electrical engineering to engineering education research correspond to many of the cited attrition factors previously detailed. She is aware that her identity as a first-generation, White cisgender woman in engineering with her own mental health journey can lead her to seek to validate her own lived experiences. The scoping review methodology provided a framework to minimize the impact of the potential conflicts of interests and validity concerns this may bring, most notably through the consultation of a librarian with expertise in conducting reviews and the use of interrater reliability throughout the screening process. The second author is an African American cisgender woman with extensive research experience related to attrition and matriculation factors that influence students in higher education. She contributed to this work as a point of triangulation. Leveraging her research skills and knowledge, she challenged the rigor of the data analysis processes and interpretation of the findings through questions and conversations with the research team. Both authors engaged in discussions about all research aspects of the study to confirm the validity of their interpretations of the articles, the findings, and potential implications. Both second and third reviewers were engineering undergraduate students in biomedical engineering and industrial and operations engineering, respectively. Although not authors of this manuscript, they contributed to this work by providing validity checks through challenging the assumptions made by the first author. They also aided significantly in the screening and data extraction processes.

8 | RESULTS

This ScLR identifies 19 empirical studies pertaining to engineering graduate students' mental health. Tables 4–10 present the results from this review. The results and summary statistics presented in the following sections (i.e., Summary Information on Included Studies, Demographic Information, Academic Outcomes, and Mental Health Measures, Instruments, and Findings) will be used to answer the guiding research question, *What is the current landscape of literature about engineering graduate students' mental health?*

8.1 | Summary information on included studies

Table 4 presents studies in alphabetical order. This order will be used in subsequent tables to indicate the studies that are being discussed. These 19 articles were coded for study focus, study keywords, participant and institution descriptions, journal discipline, type of engineering graduate student population analyzed, study type, methods used, and work referenced (theories and cited work). The years of publication for included studies ranged from 2001 to 2019. Table 5

TABLE 4 Summary information for the 19 studies, including focus, information on participants and institutions, keywords, discipline, and whether engineering graduate students were specifically examine in the study

Study		Focus	Participants and institutions	Keywords	Journal discipline	Pull out engineering graduated students
1	Amon (2017)	STEM women's career trajectories/ experiences in STEM leadership positions	46 graduate students and postdoctoral fellows (STEM) from a large public research university	Career, gender/sex, leadership, stereotypes	Psychology	No
2	Burt et al. (2018)	Role strain for Black male students, focus on ecological and sociological barriers	21 graduate students from a Midwestern University	Coping, gender/sex, isolation, microaggressions, persistence, race/ethnicity, racial fatigue, role strain, structural racism and barriers, well-being	Education	Yes (quotes)
3	Carter-Veale et al. (2016)	The effectiveness of a Dissertation House program to increase retention and PhD completion	Study 1: 1304 doctoral students (451 current) Study 2: 267 doctoral students Participants from three University of Maryland campuses (College Park, Baltimore, and Baltimore County)	Community, degree completion, dissertation writing, social support	Education	No
4	Cross (2001)	Role of gender on performance and ability in grad school; Relationship between perceptions of environment and self-evaluations of stress and self-esteem	101 graduate students from Colleges of Engineering and Natural Sciences at a large Southwestern University	Academic environment, gender/ sex, self-esteem, stress	Psychology (Applied)	No
5	Delaine and Fontecchio (2009)	The use of an online social platform (Facebook) to create a support space for minorities in STEM	Graduate students in the Philadelphia Bridge to the Doctorate program, which includes students from Drexel University, Delaware State, Temple University, and the University of Delaware	Collective knowledge, online social platforms, race/ethnicity, underrepresented minorities	Engineering Education Research	No
6	Fisher et al. (2019)	Relationship departmental structure and belonging, look across race and gender	283 graduate students; 114 from UC Berkeley, 110 from UCLA, 125 students from Stanford, and 150 from Caltech	Gender/sex, program structure, race/ethnicity, sense of belonging, underrepresented minorities, well-being	Science and Medicine	No
7	Hyun et al. (2007)	International graduate students' mental health needs, knowledge of services, and factors influencing help-seeking behavior	3121 graduate students from a large Western University	Citizenship/nationality, help-seeking, resource knowledge and utilization, well-being	College Health	No
8	Li and Stodolska (2006)	The interplay of translational status and leisure experience for Chinese international graduate students	16 graduate students enrolled at the University of Illinois at Urbana-Champaign	Citizenship/nationality, leisure, transnational experiences, well-being	Leisure	Yes (quotes)
9	Liao and Wei (2014)	Interplay of cultural values, psychological variables, experiences, and psychological outcomes for Chinese international students	370 (188 graduate) students from two Midwest institutions, one West Coast and one East Coast	Academic confidence, citizenship/nationality, cultural values, familial recognition, self-worth	Psychology (Applied)	No

TABLE 4 (Continued)

Study		Focus	Participants and institutions	Keywords	Journal discipline	Pull out engineering graduated students
10	Lipson et al. (2016)	Variations in student mental health and help-seeking across academic disciplines	15,852 graduate students (9872 masters 5980 doctoral) from 81 US institutions, most 4-year (94.9%)	Help-seeking, resource utilization	College Mental Health	Yes (data table, data points)
11	Lubinski et al. (2006)	The SAT captures information more than book-learning potential that can be used to track human capital	547 graduate students, institutions not given	Career life satisfaction, predicting occupational success	Psychology	No
12	McGee and Bentley (2017)	Effect of racialization on experiences and well-being of Black women in STEM	3 (2 doctoral) students, one from a Southern HWI and one from a Southern HBCU	Gender/sex, race/ethnicity, race-gender bias, structural racism and sexism	Learning Science and Education	Yes (quotes)
13	McGee et al. (2019)	Black student experiences related to stress and strain and the associated coping habits	48 doctoral students from 10 different institutions, 9 of which are from HBCUs	Academic performance anxiety, coping, race/ethnicity, racial battle fatigue, role strain, strain, stress	Education	Yes (quotes)
14	Mikal et al. (2015)	Use of the Internet to establish a support network for Chinese international students	8 graduate students (3 masters, 5 doctoral), 1 postdoc from a major Public University in California	Citizenship/nationality, collective knowledge, coping, help-seeking, internet usage, social support	Education	Yes (quotes)
15	Posselt (2018)	Factors influencing doctoral student persistence and well-being, defining a framework for holistic faculty support	29 doctoral students from two well-known research universities in two different regions of the United States	Persistence, social support, validation, well-being	Education	Yes (quotes)
16	Rice et al. (2009)	International graduate students advising experience, look across gender or major area of study	358 graduate (53 masters and 305 doctoral) students from the University of Florida (Gainesville, FL)	Advising relationship, citizenship/nationality	Psychology (Applied)	Yes (data table, data points)
17	Rice et al. (2012)	Comparing sources of stress and mental health of Chinese and Asian Indian students	295 (72% engineering) graduate students from a major US university	Academic pressure, acculturative stress, citizenship/nationality, depression, self-critical perfectionism	Psychology (Applied)	No
18	Torres et al. (2010)	Obstacles overcome during doctoral studies and influence on mental health	Study 1: 97 African American students enrolled in universities across the state of Florida Study 2: 174 (120 current) African American doctoral students, students enrolled in over 45 different colleges and universities, most HWIs (92.4%), some predominantly African American institutions (5.7%), and some neither (1.9%)	Coping, depression, isolation, race/ethnicity, racial discrimination and microaggressions, stress	Psychology (Applied)	No
19	Zhou (2014)	Challenges faced by Chinese international students, motivation to persist and influence of cultural factors	6 doctoral students from American Northeastern University, a midsized Public Research University.	Advising relationship, citizenship/nationality, loneliness, motivations to persist, program dissatisfaction	Education	Yes (quotes)

Abbreviations: HBCU, historically Black colleges and universities; HWI, historically White institution.

TABLE 5 Descriptive statistics on included studies' type, methods, participants' degree of study, and theories/cited work

Study information	Number of studies (%)		Specific studies																	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Type of study																					
Observational	18	(95)	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Intervention	1	(5)			x																
Methods																					
Qualitative	12	(63)	x	x	x		x			x				x	x	x	x	x		x	x
Document analysis	2	(11)	x				x														
Interviews	8	(42)	x	x						x				x	x	x	x				x
Observations	0	(0)																			
Surveys	3	(16)			x													x		x	
Quantitative	10	(53)			x	x		x	x		x	x	x					x	x	x	
Descriptive statistics	9	(47)			x	x			x		x	x	x					x	x	x	
Inferential statistics	10	(53)			x	x		x	x		x	x	x					x	x	x	
Hypothesis testing	1	(5)			x																
Modeling	3	(16)						x										x		x	
Mixed methods (both)	3	(16)			x													x		x	
Participants																					
Doctoral	6	(32)			x			x						x	x		x				x
Masters and doctoral (mixed)	5	(26)							x			x				x		x	x		
Graduate (degree not specified)	7	(37)	x	x		x				x	x		x							x	
Postdoctorates	2	(11)	x													x					
Theories/cited work	14	(74)																			
Referenced theory(s)/ concept(s)	7	(37)			x	x		x		x				x	x						x
Model(s) or framework(s)	10	(53)	x	x	x						x			x	x		x	x	x	x	
Mental health survey questions	12	(63)																			
Generated own questions	9	(47)			x	x		x	x	x		x	x	x				x			
Used existing questionnaires	6	(32)				x					x	x						x	x	x	

includes descriptive statics on information reported for each study (i.e., study type, methods, participants' degree of study, and theories/cited work).

8.1.1 | Study foci and keywords

The article's foci or goals were coded from the stated research question(s) and purposes of the studies. Some articles also explicitly stated the goals of the study. The foci and goals were then used to generate keywords, as detailed in Table 4, with the most cited across the 19 studies being citizenship/nationality (7), race/ethnicity (6), gender/sex (5), and well-being (5). We intentionally generated keywords based on reading the article rather than using the keywords provided by each article. The generated keywords were used to get a sense of the research being conducted.

8.1.2 | Participants and institutions

Participant data as reported in each study can be found in Table 4, which is categorized by graduate degree program in Table 5. Seven articles did not specify the degree type among graduate students, whereas five indicated both master's

TABLE 6 Demographic information presented for participants in the included studies

Demographics	Number of studies	(%)	Specific studies 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Academic discipline	15	(79)	x	x		x		x		x	x	x	x	x	x	x	x	x	x		x
Aerospace, aeronautical, and astronomical	2	(11)		x											x						
Chemical	3	(16)		x											x			x			
Civil	4	(21)		x											x		x	x			
Electrical, electronics, and communications	6	(32)		x						x					x	x		x			x
Industrial and manufacturing	3	(16)		x											x			x			
Materials science	4	(21)		x											x					x	x
Mechanical	4	(21)		x						x				x	x						
Other																					
Agricultural	1	(5)																x			
Bioengineering and biomedical	2	(11)		x											x						
Computer	2	(11)												x	x						
Environmental health	1	(5)													x						
Engineering, other	1	(5)		x																	
Engineering program not specified	10	(53)	x		x	x	x	x	x		x	x	x						x		
Age	12	(63)	x					x	x	x	x	x	x			x		x	x	x	x
Citizenship/nationality	9	(47)	x		x			x			x	x				x		x	x		x
Gender/sex	18	(95)	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Parent's education	3	(16)		x								x		x							
Living situation	1	(5)														x					
Race/ethnicity	9	(47)	x	x	x			x	x			x		x	x		x			x	
Relationship status	6	(32)							x		x		x						x	x	x
Year in program	11	(58)		x		x		x	x					x	x		x	x	x	x	x
Other	16	(84)	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	
Children/dependents	5	(26)						x	x				x							x	x
Financial support/income	2	(11)											x					x			
Institutional information	4	(21)		x				x							x					x	
Sexual orientation	2	(11)						x	x												
Time in the United States/ length of stay	6	(32)			x					x	x					x		x	x		

and doctoral students and six indicated only doctoral students. Two included postdoctoral researchers. Institutional data for each study is detailed in Table 4. Some articles provided the institution name(s), while others only described them (e.g., "a large public research university").

8.1.3 | Journal discipline

The 19 studies that met the study criteria came from 19 different journals. Journal disciplines included college health/college mental health (2), education (8), leisure (1), psychology/applied psychology (7), and science and medicine (1). These publications featured areas of allied health (health care professional) literature, biomedical science, behavioral science, education, health sciences, life sciences, mental health, nursing, physical sciences, psychology, public health, and social sciences.

TABLE 7 Academic outcomes presented in the included studies

Academic outcome	Number of studies (%)		Specific studies																	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Attrition/retention	2	(11)			x																x
English language	5	(26)								x	x					x			x		x
Grade point average (GPA; past and current)	7	(37)		x		x					x	x		x			x	x			
Graduation rate	1	(5)			x																
GRE test score(s)	4	(21)				x		x					x				x				
Patent record	1	(5)											x								
Post-graduation career intentions	2	(11)		x										x							
Publication rate	2	(11)						x													x
Time with advisor	1	(5)																x			
Time to degree completion	2	(11)			x			x													

Abbreviation: GRE, graduate record examination.

8.1.4 | Singling out of engineering graduate students

Engineering disciplines were determined using descriptive categories provided by the National Science Foundation (National Science Foundation, National Center for Science and Engineering Statistics, 2013). Of the 19 studies included in this review, only nine singled out engineering graduate students in their analyses. Seven studies did so with qualitative evidence via quotes. Two studies did so with quantitative evidence, one via a table and the other by simply providing a descriptive statistic.

8.1.5 | Type of study and methods used

All but one of the articles were observational studies that were closely split between quantitative (10) and qualitative (12) studies. Three of the studies used both methods. Quantitative methodologies were coded to classify the use of descriptive statistics (e.g., mean, median, mode), inferential statistics (i.e., anything with a p-value, including t-tests, regression analysis), hypothesis testing (e.g., an intervention comparing groups), and modeling (e.g., factor analysis and path modeling). Inferential statistics (10) and descriptive statistics (9) were most common, whereas modeling (3) and hypothesis testing (1) were less common. In terms of qualitative methodologies, we coded for document analysis (e.g., photographs, collected materials, artifacts), interviews (e.g., one-on-one questioning, focus groups, case studies), observations (e.g., watching in natural environments), and surveys (i.e., open-ended questions). Interviews (8) were the most common, followed by surveys (3) and document analysis (2). Observations were not conducted or included in any of the studies.

8.1.6 | Work referenced

Due to the articles' different writing styles and journal homes, we decided to be less stringent about what was included when coding this section. That is, any theory, concept, framework, or model that was mentioned was included here. Relevant theories and concepts were more likely to be found in the introduction, background, and motivation sections, whereas relevant models and frameworks were likely discussed in the methods and results sections. Theories and

TABLE 8 Specifics on academic outcomes presented in the included studies

Academic outcome and main use/findings (number of studies; %)	Study cited
Attrition or retention (2; 11%)	
Intervention increased retention by 64% (96% compared to 67%)	3; Carter-Veale et al. (2016)
Misalignment in expectations (e.g., advisor, US tenure-job market, faculty life) alluded to harm retention	19; Zhou (2014)
English language (5; 26%)	
English was a barrier; preferred leisure activities with those from the same ethnic background and who spoke Chinese	8; Li and Stodolska (2006)
English was a barrier; English proficiency (in writing, reading, listening, speaking, and overall) correlated negatively with acculturative stress	9; Liao and Wei (2014)
English language and culture were barriers in forming friendships	14; Mikal et al. (2015)
English was a barrier; higher levels of acculturation stress and lower levels of English competency/cultural awareness in Chinese students	17; Rice et al. (2012)
English was a barrier	19; Zhou (2014)
GPA (past and current) (7; 37%)	
Provide a context of the strong academic backgrounds	2; Burt et al. (2018)
Compared women and men's academic performance, finding no statistical difference in their previous or current performance	4; Cross (2001)
Correlation analysis on GPA and other metrics against psychological effects, finding no statistically significant correlation	9; Liao and Wei (2014)
Weigh response data for quantitative analysis	10; Lipson et al. (2016)
Criterion for including participants in the study	12; McGee and Bentley (2017)
Students felt supported when advisors looked at a poor GPA or course performance as a metric of short-term ability versus long-term capabilities	15; Posselt (2018)
More likely to report higher levels of rapport and satisfaction with advisors if doing well academically	16; Rice et al. (2009)
Graduation rate (1; 5%)	
The program increased the likelihood of graduation by 92%; 76% graduated in program compared to 42% not	3; Carter-Veale et al. (2016)
GRE test score(s) (4; 21%)	
Compared women and men's academic performance, finding no statistical difference	4; Cross (2001)
Covariate for quantitative analysis	6; Fisher et al. (2019)
Inclusion criterion for study participants	11; Lubinski et al. (2006)
Validate feelings of self-doubt and not belonging in their program; advisors' responses helped combat doubts and support their well-being	15; Posselt (2018)
Patent record (1; 5%)	
Proxy for career success; higher rate than the general public	11; Lubinski et al. (2006)
Post-graduation career intentions (2; 11%)	
Presented as part of the participant profile	2; Burt et al. (2018)
Experiences changed career paths (i.e., workshop encouraging students of color pursue faculty positions versus sexual assault, racial/gender stereotyping)	12; McGee and Bentley (2017)
Publication rate (2; 11%)	
Black students ~3X less likely to be published in an academic journal; mediated by perceived readiness, sense of belonging, and thoughts on program structure; students with a higher perception of success more likely to publish	6; Fisher et al. (2019)
Proxy for research productivity; students unhappy with progress and advisor	19; Zhou (2014)

(Continues)

TABLE 8 (Continued)

Academic outcome and main use/findings (number of studies; %)	Study cited
Time with advisor (1; 5%)	
Longer in a program, less likely to identify with an advisor or seek guidance; those not satisfied would intentionally increase separation	16; Rice et al. (2009)
Time to degree completion (2; 11%)	
Funding model motivated quicker completion of dissertation and degree	3; Carter-Veale et al. (2016)
Covariate for quantitative analysis	6; Fisher et al. (2019)

Abbreviations: GPA, grade point average; GRE, graduate record examination.

concepts were used as references to ground and motivate the research, whereas models and frameworks were used to guide the methodology and subsequent analysis. These were coded for separately.

A total of 13 different concepts or theories were cited across seven articles. Racial battle fatigue (Smith et al., 2011; Smith, 2004) was the only theory/concept cited multiple times (twice). This was defined as "a response to the distressing mental/emotional conditions that result from facing racism daily" (Smith, 2004, p. 180) that can cause debilitating psychological and physiological stress (McGee & Bentley, 2017; McGee et al., 2019). There were 16 different models or frameworks cited across 10 articles. Grounded theory (Corbin & Strauss, 2008; B. Glaser, 1998; B. G. Glaser & Strauss, 1967; Strauss & Corbin, 1990) was cited in four studies (Amon, 2017; Burt et al., 2018; Rice et al., 2009; Torres et al., 2010), generally as a methodological approach to the study design or analysis. The acculturation framework/model (Berry et al., 1987) was cited twice (Liao & Wei, 2014; Rice et al., 2012). This framework/model is used to discuss assimilation to different cultures. It was used to help depict the process from acculturation experiences in the academic setting to adaptation, measured through mental health outcomes. All other concepts, theories, models, and/or frameworks were cited in only one article.

8.2 | Demographic information

Of the demographics coded for detailed in Table 6, four were reported in at least half of the articles: gender/sex (18), academic discipline (15), age (12), and year in the program (11). Academic disciplines were coded by mapping disciplines to the National Science Foundation's classification of engineering fields of study (National Science Foundation, National Center for Science and Engineering Statistics, 2013). Seven unique disciplines were reported across eight articles. Of these, electrical, electronics, and communications engineering was cited the most in six articles, followed by civil engineering, materials science engineering, and mechanical engineering, each being cited in four articles. This was followed by chemical engineering and industrial and manufacturing engineering, each being cited in three articles, with aerospace, aeronautical, and astronomical engineering being cited in only two articles. Four articles reported disciplines NSF reports as "OTHER," and 10 articles did not report specific disciplines.

Participants' citizenship/nationality was reported at the same frequency as race/ethnicity (9), with relationship status (6), and parents' education (3) being reported less frequently. Finally, the participants' living situation was not directly reported in any of the studies, but one study asked about roommates. The first reviewer coded all responses to determine if any patterns appeared across studies that may have been missed. Anything reported in more than one study was included. Five additional pieces of information were coded for financial support/income (2), sexual orientation (2), institutional information (4), children/dependent status (5), and time in the United States/length of stay (6).

8.3 | Academic outcomes

We coded 10 academic outcomes, as detailed in Table 7. Table 8 presents the main uses and findings of each of these academic outcomes by study. Four studies did not include any academic outcomes (Amon, 2017; Delaine & Fontecchio, 2009; Hyun et al., 2007; McGee et al., 2019). From the other 15 studies, grade point average (GPA) was

TABLE 9 Mental health-related survey instruments cited in the included studies

Survey instrument name	Mental health topic; number of items	Survey citation
Academic Competence subscale from Contingencies of Self-Worth Scale	Extent to which one bases self-worth on academic achievement; 5-items	(Crocker et al., 2003)
Advisory Working Alliance Inventory	Three dimensions of advising relationships (rapport, identification–individuation, and apprenticeship); 30-items	(Schlosser & Gelso, 2001)
Almost Perfect Scale–Revised	Self-critical perfectionism; 12-items	(Slaney et al., 2001; Slaney et al., 2002)
Behavioral Attributes of Psychosocial Competence Condensed Form	Psychosocial competence culturally specific to the mainstream United States; 13-items	(Zea et al., 1996)
Center for Epidemiological Studies–Depression scale (CES-D) and CES-D Short Form	Full: assesses participants' severity of depressive symptoms at both measurement occasions; has been used extensively with ethnic minority samples; 20-items Short Form: assess depressive symptoms during the past week; 10-items	Full: (Radloff, 1977) Short Form: (Cole et al., 2004; Radloff, 1977)
Daily Life Experience-Frequency Scale (DLE-FS), subscale of the Racism and Life Experience scale	Assesses the frequency and impact of experiencing 20 racial microaggressions; 20-items	(Harrell, 1994)
Family recognition through achievement (FRTA) subscale from Asian Values Scale-Multidimensional (AAVS-M)	Level of adherence to the value of bringing honor to one's family by achieving academically and doing well occupationally; 14-items	(Kim et al., 2005)
Generalized Anxiety Disorder 7-item (GAD-7)	Measures symptoms of generalized anxiety disorder; 7-items	(Spitzer et al., 2006)
Inventory of College Challenges for Ethnic Minority Students (ICCEMS)	Academic stress due to struggles with academic challenges and difficulties in expressing oneself in academic settings; 5-items	(Ying et al., 2004)
Patient Health Questionnaire-9 (PHQ-9)	Nine core symptoms of a major depressive episode and measures anxiety (panic and generalized anxiety disorder); 9-items	(Spitzer et al., 1999)
Perceived Stress Scale (PSS)	Subjective global stress, assesses individuals' appraisal of their lives as unpredictable, uncontrollable, and overloaded; 10 items	(Cohen et al., 1983; Cohen & Williamson, 1988)
Positive Affect subscale from the Positive and Negative Affect Schedule Scale (PANAS)	Experiences of pleasurable engagement with the environment; 10 items	(Watson et al., 1988)
Self-Esteem Scale	Self-esteem; 10 items	(Rosenberg, 1965)
Societal, Attitudinal, Familial, and Environmental Acculturative Stress Scale–Short Form (SAFE)	Acculturative stress in social, attitudinal, familial, and environmental contexts; 24-items	(Mena et al., 1987)
Survey on Doctoral Education and Career Preparation	Aspects of the advising experience; 8-items	(Golde & Dore, 2001)

cited the most (7), followed by the English language (5), and graduate record examination (GRE) test scores (4). GPA and GRE test scores were cited to benchmark students' academic achievements or to compare groups. The English language was discussed in every study, specifically English proficiency being a factor in international students' educational experiences (e.g., difficult social interactions or increased acculturative stress levels). Several academic outcomes were found in only two studies: attrition/retention, post-graduation career intentions, publication rate, and time to degree completion. Attrition and retention were used to assess an intervention's success (along with graduation rate and time to degree) and provide insight into a potential consequence of a misalignment in graduate school expectations for international students. Similarly, career intentions post-graduation indicated how students' experiences altered their intended career paths (e.g., from academia to industry). Publication rate was used to assess research progress and to

TABLE 10 Mental health measures discussed in the included studies

Variables	Number of studies	(%)	Specific studies 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Anxiety	4	(21)										x			x	x	x				
Coping habits	7	(37)		x			x			x				x	x		x			x	
Depression	5	(26)						x				x			x				x	x	
Emotion(s)	11	(58)	x	x	x		x	x	x		x			x		x	x				x
Existing mental health problem	2	(11)							x			x									
Life satisfaction	4	(21)	x							x			x								x
Relationship(s)	13	(68)	x	x	x		x	x	x				x	x	x	x	x	x			x
Family	4	(21)	x						x							x					x
Friends	6	(32)	x	x			x		x							x					x
Roommates	1	(5)														x					
Spouse/significant other	2	(11)							x				x								
Advisor	9	(47)	x	x	x				x					x	x		x	x			x
Peers	11	(58)	x	x	x		x	x	x					x	x	x	x				x
Self-harm	1	(5)										x									
Non-life-threatening	1	(5)										x									
Suicidal	0	0																			
Suicidal ideation	1	(5)										x									
Stress	11	(58)			x	x		x	x		x			x	x	x			x	x	x
Treatment utilization	1	(5)										x			x						
Well-being	5	(26)		x		x		x							x	x					x
Work-life balance	6	(32)	x		x					x			x		x	x					
Other	12	(63)	x	x	x	x		x			x			x	x		x		x	x	x
Gender stereotypes/sexism	4	(21)	x	x										x	x						
Motivation to persist	2	(11)													x						x
Perceptions of environment	2	(11)				x		x													
Perceptions of self/self-esteem	3	(16)				x		x			x										
Racial stereotyping/role strain	5	(26)		x										x	x		x			x	
Self-critical/imposter syndrome	2	(11)													x				x		
Social support/sense of belonging	11	(58)	x	x	x		x	x			x			x	x	x	x			x	

explore racial/ethnic variation in publication rate. Time to a degree was also used as a covariate in the analysis. Graduation rate, patent records, and time with an advisor were each coded for in one study. Time with an advisor was used to examine that relationship, whereas patent records were used to assess career success.

8.4 | Mental health measures and instruments

8.4.1 | Mental health instruments cited

Only survey questions or items that directly related to mental health measures were included. Although demographic questions can relate to mental health measures, such as relationship status, they tended to be more general and were therefore omitted. As detailed in Table 5, 12 of the studies included surveys with mental health-related questions. Nine of those studies had specific questions that the researchers had created for their study and six studies used existing

questionnaires. Three studies included both existing questionnaires and created their own questions. Table 9 details the cited mental health questionnaires used across these six studies, the topics covered, the number of questions asked, and the citation for the survey instrument. From these instruments, 15 unique surveys were cited. The Perceived Stress Scale (Cohen et al., 1983; Cohen & Williamson, 1988) was used in two of the six studies, and the Center for Epidemiological Studies–Depression scale was used in both its full form in one study and short form in another study (Cole et al., 2004; Radloff, 1977). Depression and perceived stress were the topics of two of the surveys; topics appearing only once include academic stress, acculturative stress, advising experiences, advising relationships, psychosocial competence, engagement with the environment, familial values, generalized anxiety disorder, the impact of racial microaggressions, perfectionism, self-esteem, and self-worth. These topics were also measures that were directly coded or included as the main findings of the paper.

8.4.2 | Mental health measures

There were 13 major mental health measures across the 19 studies, as detailed in Table 10. Relationship(s) were cited in 13 studies, with peers being cited the most frequently (11), followed by an advisor (9), friend(s) (6), family (4), spouse or significant other (2), and roommates (1). Emotion(s) and stress were both cited in 11 studies, with emotions coded for anything regarding feelings or affective states (e.g., happy, sad, angry, etc.). Coping habits were cited in seven studies and work-life balance in six. Depression and well-being were both cited in five studies, whereas anxiety and life satisfaction were cited in four. Existing mental health problem(s) were cited in two studies. Treatment utilization, non-life-threatening self-harm, and suicidal ideation were each cited in one study. Fourteen of the 19 studies included some other mental health measure. As with the demographic measures, the first reviewer coded all responses to determine if any patterns may have been missed, identifying seven additional measures mentioned more than once, across 12 studies. Social support and/or sense of belonging were cited the most across 11 of the studies. This was followed by racial stereotyping/role strain (5), gender stereotypes and/or sexism (3), and perceptions of self and/or self-esteem (3). Motivation to persist, perceptions of the environment, self-criticism, and/or imposter syndrome were each reported in two studies.

8.5 | Mental health findings

After the mental health measures were coded, each study's main mental health findings were synthesized. The main findings for each study were grouped into five categories: social support and sense of belonging; student–advisor relationship; cultural barriers faced by international students; gender and racial stereotypes; and generalized findings. A short write-up of these findings by category and study appears in the Appendix (Table A1).

8.5.1 | Social support and sense of belonging

Social supports and sense of belonging were discussed in 11 studies (Amon, 2017; Burt et al., 2018; Carter-Veale et al., 2016; Delaine & Fontecchio, 2009; Fisher et al., 2019; Liao & Wei, 2014; McGee et al., 2019; McGee & Bentley, 2017; Mikal et al., 2015; Posselt, 2018; Torres et al., 2010). In general, students tended to seek out peers, lab mates, or postdocs for help (Posselt, 2018). Virtual platforms and in-person community-building interventions helped build support systems (Carter-Veale et al., 2016; Delaine & Fontecchio, 2009). Chinese international students discussed the need for culturally appropriate social and emotional support (i.e., talking with friends and family), emphasizing their hesitancy to discuss mental health related topics with others (Liao & Wei, 2014; Mikal et al., 2015). Black students often felt that they were unwanted in engineering communities; these students commented on the lack of support available to them compared to their peers due to the low numbers of racially/ethnically minoritized students and faculty of color in academia (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). This is concerning as other studies showed that feeling accepted empowered students and increased their reported well-being (Amon, 2017; Fisher et al., 2019).

8.5.2 | Student–advisor relationship

The student–advisor relationship was discussed in nine studies (Amon, 2017; Burt et al., 2018; Carter-Veale et al., 2016; Hyun et al., 2007; McGee et al., 2019; McGee & Bentley, 2017; Posselt, 2018; Rice et al., 2009; Zhou, 2014). Good advising experiences provided opportunities to build trust in the relationship, which helped students visualize their future careers (Amon, 2017; Hyun et al., 2007). However, students perceived going to faculty for support as a last resort, fearing faculty would treat them differently (Posselt, 2018). Students dissatisfied with their advisors attributed this to misalignment in research interests, advising/communication styles, expected work-life balance, anticipated financial support, and expected encouragement (Burt et al., 2018; Carter-Veale et al., 2016; McGee et al., 2019; McGee & Bentley, 2017; Rice et al., 2009; Zhou, 2014).

8.5.3 | Cultural barriers international students confronted

The cultural barriers international students confronted during their graduate school experiences were discussed in six of the studies. Students discussed acculturative stress (i.e., stressors in assimilating to a new culture; Hyun et al., 2007; Li & Stodolska, 2006; Liao & Wei, 2014; Mikal et al., 2015; Rice et al., 2012; Zhou, 2014). International students' reports on their mental health problems are on par with domestic student rates; common stressors included acculturative stress, financial problems, basing self-worth on academic competence, and being self-critical (Hyun et al., 2007; Li & Stodolska, 2006; Liao & Wei, 2014; Rice et al., 2012). Chinese graduate students were also less likely to know about or access mental health resources compared to domestic students (Hyun et al., 2007; Mikal et al., 2015). Filial piety, or the respect for the burden borne by one's parents, elders, and ancestors and awareness of the obligation to repay the debt, drove individual conduct by influencing students' intentions to persist. Students experienced fear and shame at the thought of leaving their programs from the high social cost of quitting and the desire to bring honor to their families via scholastic achievement (Liao & Wei, 2014; Mikal et al., 2015; Rice et al., 2012; Zhou, 2014).

8.5.4 | Gender and racial stereotypes

Six of the studies examined gender and racial stereotypes (Amon, 2017; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Posselt, 2018; Torres et al., 2010). Minoritized students in engineering faced additional barriers in their studies, from assumptions of intellectual inferiority to discrimination; persisting in these environments required additional energy and coping strategies at the cost of their physical and mental health (Amon, 2017; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). Having faculty with shared identities helped students come forward with experiences of sexual assault or harassment (Posselt, 2018).

8.5.5 | Generalized findings

Four studies focused on generalized findings related to asking for help and levels of distress (Cross, 2001; Fisher et al., 2019; Lipson et al., 2016; Lubinski et al., 2006). Overall, engineering graduate students are less likely to ask for help concerning mental health problems despite over 25% of students meeting the criteria for self-reported mental health problems (Lipson et al., 2016). Although there were no differences in academic performance, women had higher levels of distress, perhaps due to their lower self-evaluations of intelligence (Cross, 2001; Fisher et al., 2019; Lubinski et al., 2006).

9 | STUDY LIMITATIONS

As with any review, this one has limitations. It is possible that our choice of databases or the questions used to guide the review process eliminated relevant studies. Future researchers should examine alternate study selection approaches, such as using automated text analysis or other natural language processing tools that can automate searching in the screening process, reduce human error, and access more databases. Furthermore, this ScLR does not include any

measure or rating of how well the topic of engineering graduate students' mental health is discussed. This limits recommendations that can be inferred from this study (Joanna Briggs Institute, 2015). Future research might also include information presented by renowned mental health organizations, which appear on online platforms, editorials, briefs, and more.

The findings presented here are not intended as an exhaustive list of what should be considered in terms of demographics, academic outcomes, or mental health outcomes for engineering graduate students' mental health (e.g., we did not code for financial concerns). These findings are simply a collection and synthesis of the work that has been done as of this writing. Additionally, the exclusion criteria may have excluded studies important to engineering graduate students' mental health that should be considered in future reviews. Subsequently, there is a clear need for more research.

10 | DISCUSSION

This study aims to answer the research question: *What is the current landscape of literature about engineering graduate students' mental health?* This research question guided the formation of the inclusion criteria, which, in turn, formed the screening questions. These screening questions determined study eligibility, resulting in the selection of 19 studies. This study's stringent requirements for inclusion (e.g., a US student population, peer-reviewed sources, explicitly naming engineering graduate students) may explain this small number. Nevertheless, the information collected from these papers is insightful. The main findings of this ScLR were grouped into five areas: social support and sense of community, advisor relationships, cultural barriers, gender and racial stereotyping, and generalized findings. The following sections present an interpretation of the findings in three main themes: research about engineering graduate student mental health is limited and varies greatly, the importance of graduate students' advising relationships and social supports, and more work is needed to explore the racialized, gendered, and intersectional experiences of various engineering graduate student populations.

10.1 | Research on engineering graduate students' mental health is limited and varies greatly

Searching across five databases produced only 19 papers that met the inclusion criteria. None were published in the same journal, and only one of them was an engineering-specific source (*American Society for Engineering Education [ASEE] Annual Conference and Exposition Proceedings*), although several engineering education journals exist (e.g., *Global Journal of Engineering Education*; *International Journal of Engineering Education*) and ASEE being sourced in Scopus' database (ASEE, 2021; Scopus, 2021). Unsurprisingly, research designs varied across the reviewed studies. First, five were part of larger studies that examined both undergraduate and graduate student populations, and two combined graduate students with postdoctoral researchers. Seven of the studies did not distinguish between master's, doctoral, or joint master's-doctoral degree students, suggesting interest in determining differences according to program and level is limited. Only nine of the studies specifically examined engineering graduate students' experiences in the findings (seven through quotes, two through data points), with only one study focused on only engineering graduate students. The remaining 10 studies made generalized claims concerning the entire study population, not specifying specific engineering disciplines and often including multiple academic disciplines.

Both qualitative and quantitative research methods are vital and needed to understand engineering graduate students' mental health experiences. Nine studies used qualitative methods, seven used quantitative methods, and three of them used mixed methods. In engineering education research, quantitative studies provide generalizability to a larger sample through representative sampling, whereas qualitative studies support transferability, or the application of the findings to other settings, through rich descriptions (Borrego et al., 2009). Mixed methodologies try to find a balance between these two methods to best answer the research question(s) at hand. The differing research methodologies across the reviewed studies are not as surprising given the variation in research foci (coded as study keywords in Table 8). With 10 major keywords, studies focused on academic performance anxiety, acculturative stress, predicting occupational success, self-critical perfectionism, and more. There was also variation in the theories and frameworks used to ground and motivate these works. Only seven of the 19 studies cited a theory or concept to ground and situate the work, whereas 10 studies included a model or framework that researchers used to guide the methodology or analysis. Although using past work to motivate studies and inform research designs is promising, it is intriguing that only

three of these theories or concepts were cited multiple times (racial battle fatigue, grounded theory, and the acculturation framework/model).

The demographic information coded across studies also varied. Many studies were designed to explore differences in demographic groups (e.g., gender/sex). However, over one-third of the studies did not report basic demographic information (e.g., citizenship/nationality, age). Data pertinent to well-being (e.g., living situation or parent's education level) were found in no more than two of the studies or not present at all. For instance, no study included academic milestones or on-campus resource utilization. Milestones are inherent to graduate school (e.g., candidacy, dissertation, defense, etc.), and academic resources such as writing centers may provide support to help graduate students progress in their academic careers (Kaler & Stebleton, 2019; Owens et al., 2020). Furthermore, studies had limited discussion of the impact of finances on engineering graduate students' mental health. Coming from a lower socioeconomic background can be a risk factor for depression and anxiety; additionally, a student's economic background can also impact their sense of belonging (Ostrove et al., 2011; Ridley et al., 2020).

Although several academic measures were included, none were found in more than seven studies. Those found in only one study included graduation rate, patent record, and time with an advisor. Although patient records may be a more targeted outcome, graduation rate and time with one's advisor are common metrics when discussing the state of graduate education. Time with one's advisor might also be considered as time to degree completion; however, this was only cited twice. On the other hand, GPA, GRE scores, and proficiency with the English language were the most frequently reported academic outcomes in this review. This is unsurprising as these are all metrics used in US admission processes, and can therefore be used to uniformly discuss graduate students' academic outcomes.

The mental health factors included in the studies were also surprising. Although some were cited multiple times (advisor relationship(s), emotion(s), relationships with peers, and stress), several factors were only cited once (relationships with roommates, self-harm, and treatment utilization). Most alarming is that only one study reported on treatment utilization and self-harm—and no study reported on help-seeking behaviors or suicidal ideation/attempts. Engineering students are much less likely to seek help than students in other disciplines, and not seeking help can negatively impact one's personal and professional well-being (Lipson et al., 2016). As stated earlier, delayed help-seeking can affect treatment access and efficacy, as well as lead to more severe mental health problems (Hunt & Eisenberg, 2010; Lipson et al., 2016). Given that death by suicide is the second leading cause of death in college-aged individuals and that suicidal ideation has almost doubled in the past decade, suicide and related forms of self-harm need to be studied in this population (Lipson, Lattie, & Eisenberg, 2019; Turner et al., 2013).

We identified two main concerns regarding the mental health survey instruments used. First, these instruments were published from 1965 to 2006, bringing into question the applicability of these surveys. For example, many mental health instruments do not include experiences of racism in mental health diagnosis, which can be a significant factor for self-reported mental health outcomes for African American students (Chao & Green, 2011). Second, not every study provided the exact wording for each question. Only six studies used existing questionnaires, nine studies created their own, and seven studies did not provide any information on specific mental health items generated or surveys they may have cited. Because they did not provide this information in their methods or any other details on their survey instruments (e.g., length, phrasing, question order), they raise potential validity concerns and limit how other researchers can replicate or build upon these studies.

10.2 | Advising relationships and social supports are important

Relationships formed and leveraged during graduate school can have a strong impact on students' mental health and intentions to persist. When selecting a graduate school program, prospective students are frequently advised to seek out potential advisors who they feel they can have a strong positive relationship with (Gibbs et al., 2012; Luchini-Colbry, 2017). This is for a good reason; advisors can greatly influence the graduate student experience, and difficulties in the advising relationship can lead to increased levels of depression and stress (Zhao et al., 2007). Unsurprisingly, the student–advisor relationship influenced many of the academic outcomes included in this review, including students' intentions to persist (i.e., attrition/retention), publication rates, and post-graduation career intentions. A positive experience with an advisor contributed to feelings of trust, support, and affirmed commitment to their work being (Amon, 2017; Posselt, 2018). In contrast, negative experiences resulted in reliance on other supports and coping strategies to continue their studies (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017). This may indicate the role of a faculty advisor and research context is more important for students' success than other measures. Recent work at

an Australian university showed that students' research environment, namely the research field and their advisor, had a significant impact on academic outcomes (i.e., publications, citations, attrition rates), whereas a student's preparation (i.e., prior academic outcomes and research training) had minimal influence at most (Belavy et al., 2020). This once again highlights the importance of the advising relationship in a graduate student's academic career and the importance of universities supporting both the students and advisors in this relationship, especially for minoritized individuals.

The lack of social support for minoritized students in engineering within their lab, program, and school environments can make the relationship between student and advisor critical to student well-being (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017). One study in this review found almost a quarter of international students would change their advisor if they could (Rice et al., 2009). Engineering graduate students who identified as Black, women, international, and/or a combination of these identities persisted in their programs despite the multitude of barriers they encountered. Their experiences ranged from their advisor being inaccessible to being told that they were not capable of graduate work and therefore did not belong (Burt et al., 2018; McGee & Bentley, 2017; Torres et al., 2010). They faced a myriad of racial- and gender-based stereotyping that further tainted their relationships with their advisors. In addition to such discriminatory practices, misalignment in research interests, poor communication, and unrealistic expectations for a work-life balance could tarnish the advising relationship. These concerns were also echoed by graduate students who considered their advisor as a last resort for social or emotional support. Students' fears of being stigmatized, dismissed, or further discouraged made faculty an inaccessible resource for many (Posselt, 2018). Given these factors, students would often turn to emotionally draining, unhealthy coping strategies (e.g., self-preservation via intentional distancing from advisor) to function in hopes of still obtaining their degrees (Stallman et al., 2021). Although both students and advisors are responsible for the quality of their relationship, the inherent power imbalance and lack of required formal training on how to manage these relationships for both parties should not be overlooked.

Research has demonstrated that finding a community outside of the advising relationship can counteract negative graduate school experiences. The utility of social support and the need for a sense of community were salient themes found across studies. Whether these communities were formed online or in person, having a space to talk about graduate school life, concerns individuals were facing, feelings of isolation and doubt, and more helped students feel supported in their graduate studies (Amon, 2017; Delaine & Fontecchio, 2009; Mikal et al., 2015; Posselt, 2018); that is, the presence of social supports served as a mechanism to help students cope with their graduate school experiences and to persist. In one intervention, communities of all-but-dissertation doctoral students improved retention rates by 64% and the likelihood of graduation by 92% (Carter-Veale et al., 2016). Similar interventions using cohort model approaches with professors and/or peers provide emotional support and a supportive environment (Bista & Cox, 2014). These supports were crucial to students' experiences and ability to cope with the stressors they faced. The most frequently reported mental health measures echoed this: emotion(s), relationships with peers, stress, and advisor relationship(s). Graduate students' mental health experiences largely depend on their environment and who they interact with. The relationships students form with their peers, advisor(s), faculty, and others are vital to the socialization process in transitioning to graduate school, where new students try to understand graduate school norms (e.g., navigating coursework, program environment, research, degree milestones, time commitment, etc.; Gardner & Barnes, 2007; Joseph, 2012; Turner & Thompson, 1993). As most students are adjusting to graduate school, it is not surprising that their personal and academic relationships are often tied to emotional responses and stress. Such relationships might provide social support or a source of stress and anxiety (Grady et al., 2014). However, the reviewed studies often ignored these relationships (e.g., students' living situations). Feelings of isolation and not belonging are fundamentally rooted in the presence and strength of social relationships. Research has demonstrated that social self-efficacy, or the confidence to use social skills to initiate and maintain relationships, can mitigate the reported severity of depression and thoughts of suicidal ideation for science, engineering, and mathematics graduate students (Bork & Mondisa, 2019). These relationships can exist in engineering graduate students' personal, professional, and academic lives, as well as any intersection of these. Supporting the growth and longevity of social supports can promote positive mental health experiences by promoting positive coping strategies and fostering a sense of belonging (Jensen & Cross, 2021).

10.3 | More work is needed to explore the racialized, gendered, and intersectional experiences of various graduate student populations

Future work is needed to better understand the mental health experiences of international, Black, women and Black women engineering students. Every study that focused on international graduate students discussed how the stress of

being in majority English-speaking environments severely impacted their day-to-day interactions in the United States. Given the lack of non-English-focused language training and limited exposure to other countries' cultures in US higher education, many international students felt overwhelmed when trying to create and sustain relationships. Erichsen and Bolliger (2011) discuss that prior to coming to study in the United States, international students would like more information about academic cultures, established systems to assist transitions from educational settings to social settings, and additional structured opportunities to discuss research and professional development. This information could help offset feelings of isolation, which have been linked to negative outcomes, including attrition (Ali & Kohun, 2006; Laufer & Gorup, 2019).

In comparison, papers from this review demonstrate that Black graduate students are implicitly and explicitly told that they do not belong in engineering and are not expected to succeed (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). Despite these barriers, students persist, but often at the cost of their emotional and physical well-being. Franklin (2019) indicates that some coping mechanisms can help lower the psychological and behavioral stress that students experience from racial microaggressions. It is beneficial for minoritized students to have skills (e.g., coping mechanisms) to help them navigate these environments. However, this fails to recognize the systems and structures in place that enforce the hostile environments in which these students operate (McCluney et al., 2021). For change to occur, accountability must be required of these systems and structures, not the minoritized students experiencing and navigating these hostile environments.

There is also an imperative need to study the intersectional mental health experiences of women and minoritized women in engineering graduate programs to identify targeted ways to support their well-being and persistence. Women were often perceived as less capable, both by themselves and others, despite performing on par with men in every study in this review (Amon, 2017; Cross, 2001; Fisher et al., 2019). Women in science and engineering often feel that they are working at an increased pace and with a higher workload than their male counterparts, and report high levels of isolation, all of which can negatively impact their commitment to their careers (Litzler et al., 2005). Black women graduate students are subject to both racial and gender stereotyping in their day-to-day interactions. Explained by the concept of intersectionality (Crenshaw, 1989), Black women engineering graduate students' experiences can be highlighted by their intersecting minoritized identities of being both Black and women; that is, they experience compounding stressors from both race-based and gender-based discrimination and harassment. The limited findings from this review support the increasing calls to explore the role that intersecting identities (i.e., race and gender) have on mental health (Banks et al., 2002; Jackson, 2020).

The evidence presented in this review demonstrates that many gaps exist in engineering graduate students' mental health research. These limited findings are in alignment with a report by the National Academies, which states: "[T]he research on wellbeing and mental health for graduate students remains limited in comparison to undergraduate students ... effective support for graduate students would benefit from increased research and program evaluation" (NASEM, 2021, p. 83). In sum, there is much work to be done. The following sections discuss the implications of this work for engineering education and areas for future research.

11 | IMPLICATIONS FOR ENGINEERING EDUCATION

This work identifies three potential opportunities for the engineering education research community: (1) an opportunity to better understand graduate students' mental health in engineering, (2) a need for the creation of a consistent language for discussing mental health, and (3) a need to use existing theory and frameworks when examining mental health issues. Most of the work on engineering graduate student mental health has focused on observing and broadly characterizing the state of mental health problems. First, additional work is needed to understand the current state of graduate student mental health, including how these problems form, persist, and can be prevented. The studies discussed in this work are few and largely disjointed. They spanned a variety of disciplines, including psychology, health/medicine, higher education, and engineering. There was no clear consensus on how research concerning engineering graduate students' mental health should be conducted, including what variables should be included and how those variables are defined and operationalized. To make progress in this work, researchers must help create consistency in how mental health outcomes are defined, studied, and communicated.

Second, there is a need for the creation of a consistent language for discussing mental health. A lack of shared nomenclature has contributed to the variability and inconsistency in mental health measures used and academic outcomes explored, as found in these results, and in turn, may create future disjointed work. A lack of shared terminology

can make it difficult to compare findings across studies and may hinder future researchers from building on existing work (Schmidt & Hansson, 2018). Our call for co-created terminology and communication across disciplines via conscious efforts (i.e., considering research goals, researcher backgrounds, and personalities) supports existing research (Marzano et al., 2006). Moving forward, researchers need a defined set of vocabulary and guidelines for best practices when doing this work.

Finally, to help create change, researchers must be cognizant of past work. Future research must be grounded in existing theories, frameworks, and findings across different fields. Engineering education researchers have a history of drawing on the research traditions of many disciplines, including education and social science, as well as engaging in diverse research methods (Radcliffe, 2006). This review indicates future researchers should examine and use theories prevalent in other academic disciplines, such as psychology, medicine, social sciences, and public health, to both situate their work and propose new theories and frameworks to understand engineering graduate students' experiences with mental health. This can help foster new relationships and partnerships among the many different disciplines and stakeholders interested in this field of study.

12 | FUTURE RESEARCH AND PRACTICE

This review helps to identify several salient opportunities for future research and practice: (1) seek to standardize what is reported, (2) explore both positive and negative mental health outcomes, (3) explore population-level data, (4) purposefully explore the experiences of minoritized, marginalized, and underrepresented students, (5) expand research on the student–advisor relationship, (6) explore the role of social supports outside of the advising relationship, and (7) increase research and dissemination on mental health interventions.

The first recommendation for standardization begins with providing basic summary descriptive statistics of demographics, standard mental health measures, and academic outcomes in research conducted, as detailed in Table 11. This work has demonstrated a need to challenge assumptions of heterogeneity in mental health experiences based on core identity groups (e.g., race, gender, nationality, etc.). Future work should include details of the intersections of variables that are known to impact one another as they relate to desired outcomes. Although Table 11 focuses on individualistic traits, when studying mental health, it is equally important to consider what and how current systematic structures can impact individuals' mental health (Garcia et al., 2017; Pearson et al., 2022). For example, how would an institution's size or culture impact students' comfort with reporting experiences of assault or seeking help in those situations?

The second recommendation is to include both positive and negative measures when reporting mental health outcomes. To promote positive mental health experiences, researchers must first uncover what these are and how they are experienced. For example, interviews could be conducted to ask graduate students to reflect on how they celebrate their successes. The third recommendation is that researchers must explore population-level data for engineering graduate students (e.g., via the Healthy Minds Network Healthy Minds Study, the American College Health Association's National College Health Assessment, etc.). This may help uncover what experiences are shared and what experiences are distinct in a setting with students from a variety of backgrounds and experiences. For example, presenting differences in reported outcomes by race, gender, ethnicity, nationality, and their potential intersections can provide vital information for specific communities, as well as highlight how the population overall is coping.

Fourth, future work needs to build on and expand the mental health experiences of international, Black women, and Black women graduate students by utilizing targeted sampling strategies to explore these populations' experiences. This should include Indigenous and Latinx graduate students, who were not the focus of any studies. In addition, no study in this review discussed the experiences of transgender or non-binary engineering graduate students or provided results outside of a sex-based gender dichotomy. Students whose gender does not match their gender assigned at birth or is outside of the female–male binary are four times more likely to have at least one mental health problem, and over three times more likely to have seriously considered suicide in the past year (Lipson, Raifman, et al., 2019). Future work also needs to expand to include underrepresented graduate student groups (e.g., first-generation, gender-nonconforming, lower socioeconomic backgrounds, veterans, etc.).

Similarly, regardless of method choice (i.e., qualitative, quantitative, mixed methods), researchers should first consider their positionalities and biases that can impact the work, as not doing so can raise serious validity concerns for the findings (Garcia et al., 2017; Hampton et al., 2021; Pearson et al., 2022; Secules et al., 2021). It is equally important to elect methods that adequately answer the research question(s) posed. For example, qualitative methods or mixed

TABLE 11 Metrics to consider including in future studies on engineering graduate students' mental health

Demographics
Academic discipline (and sub-discipline)
Age
Children/dependent status
Citizenship/nationality
Disability status
Race/ethnicity
Financial support/income (past, current, and future)
First-generation status
Gender/sex identity
Living situation
Relationship status
Socioeconomic status (past, current, and anticipated future)
Sexual orientation
Time in the United States/length of stay
Veteran status
Year in program
Academic Outcomes
Academic/degree milestones
Attrition/graduation rate/retention
English language competency
GPA (past and current)
Post-graduation career intentions
Publication rate (conferences, manuscripts, author order)
Research environment/climate
Resource utilization (e.g., writing centers, financial assistance, etc.)
Time to degree completion (anticipated, actual)
Time with advisor
Mental Health Outcomes
Coping habits
Emotions (feelings or affective states)
Existing mental health problem(s) (e.g., anxiety, depression, stress, etc.)
Help-seeking and treatment utilization
Life satisfaction
Motivation(s) to persist
Perceptions of environment
Perceptions of self/self-esteem
Relationship(s) (advisor, friends, family, peers, and/or significant other)
Self-harm and/or suicidal ideation
Self-image (e.g., imposter syndrome)
Sense of belonging
Work-life balance

Abbreviation: GPA, grade point average.

methods could be used to explore minoritized engineering graduate students' lived experiences and any culturally relevant factors that may influence these experiences. This could help ensure that the mental health experiences of minoritized populations are being holistically considered and aligned with the aforementioned recommendation (NASEM, 2021). Chao and Green's (2011) multiculturally sensitive mental health scale provides an acute example of how to examine experiences of racism in a mental health diagnostic instrument. Although their scale targeted African Americans, leveraging similarly mixed research methods could enable an expansion of these instruments to improve the assessment of minoritized engineering graduate students' experiences.

The fifth recommendation is to expand research on the student–advisor relationship. This relationship is central to graduate students' experiences, and a positive relationship with one's advisor can help reduce burnout and improve overall experiences (Nagy et al., 2019). Future work might explore the implementation of formal training for all graduate student faculty advisors on ways to create an environment that promotes students' well-being, such as at the University of Minnesota's Chemistry department. Researchers shared how the department worked to help support students' mental health by empowering students and revising departmental policies to increase feedback from their advisors (Mousavi et al., 2018). Similarly, a recent study at 12 colleges and universities found that faculty welcomed professional development training about students' mental health and that over half believed it should be mandatory (Boston University School of Public Health et al., 2021). NASEM recommends institutions of higher education "provide and require faculty training on how to create an inclusive and healthy learning environment" (NASEM, 2021, p. 15). These trainings could make a difference in students' ability to seek support in serious cases of assault and discrimination, potentially improving their academic and professional careers.

The sixth recommendation is to extend research on social support past the advising relationship. As discussed previously, experiences students have within their program, department, and institution can influence their mental health. For example, the impacts of mentoring ecosystems could be explored to understand how moving past the traditional student–advisor model can improve students' feelings of isolation, lack of support, and poor sense of belonging (Mondisa et al., 2021). Other studies could explore interventions like the Dissertation House Institute (DHI), but with different academic milestones (e.g., first semester on campus, candidacy exams; Carter-Veale et al., 2016).

This extends to the seventh recommendation, to increase the number of intervention studies. If engineering education researchers do not understand for whom, why, or how mental health problems persist in this population, it is difficult to consider what interventions should be initiated. Although current research can point to factors and variables important to engineering graduate students' mental health, without interventional studies we do not know what efforts lessen or prevent mental health problems. For example, international students called for more explicit discussions on the norms and expectations of graduate school (Erichsen & Bolliger, 2011). There are the beliefs, values, and assumptions each discipline has about its practices, coined as the "hidden curriculum." Although these can be communicated in the classroom (explicitly or implicitly), taught informally, or not taught at all (Villanueva, Gelles, di Stefano, et al., 2018; Villanueva, Gelles, Youmans, & di Stefano, 2018). It might be helpful for institutions to provide an introductory course for graduate students to address elements of the hidden curriculum. For example, a course might discuss professional development skills (e.g., networking, research talks, etc.), research skills (e.g., how to read scientific articles, etc.), specific retention concerns (e.g., mood disorders, funding modalities, etc.), and stigma surrounding mental health (Reavley & Jorm, 2010; Yamaguchi et al., 2013). Engineering education researchers need to embrace and adopt best practices from other fields while actively creating a community of learning to benefit all who participate. Cumulatively, these areas of research can help uncover what factors allow negative experiences to persist and what changes need to be made to better support engineering graduate students' well-being.

13 | CONCLUSIONS

This ScLR has demonstrated the limited range of work examining engineering graduate students' mental health. Of the 19 studies included in this review, eight of them have been published between 2015 and 2019. This mirrors the overall rise in focus on mental health in higher education populations. However, graduate students generally and graduate students in engineering are understudied, as this review shows. The studies did show diverse trends of research methodologies; however, the work is fragmented and lacks consistency. Given that half of the studies in this review did not specifically separate engineering graduate students in their results, engineering education researchers should help contribute to this literature.

We can leverage existing work, ground future research in established theories and frameworks, and situate the findings in the context of the field. To be successful in studying mental health, we need to work toward developing credible interview protocols and validated reliable survey instruments. These efforts will enable the expansion of research to

encompass the understanding of what is occurring in terms of graduate students' mental health, why these patterns exist, and how to prevent negative outcomes. Researchers must work to establish a set of standardized vocabulary and variables. Establishing these guidelines will help foster a community of practice about engineering graduate students' mental health. This will encourage dialogue between stakeholders already studying this field and encourage interdisciplinary collaborations. It is essential for stakeholders to be able to make informed and evidence-based individual, programmatic, and administrative decisions to improve the well-being of students. These results cannot be achieved without intentional efforts to foster communication across disciplines.

The increasing prevalence of mental health problems in higher education brings an awareness to understudied and at-risk populations. A lack of empirically-based research limits the ability to not only understand what is going on but also why it occurs. With the current state of research and the ever-increasing mental health crisis, it is vital to establish a research agenda that intentionally bridges existing disjointed efforts and progresses the understanding of systemic mental health problems. Engineering education researchers can fully explore engineering graduate students' mental health and then explain why certain patterns exist. This may lower the risk of failure for intervention and programmatic efforts addressing these needs. Robust study design and standardizing of how new findings are discussed can help inform the creation of more effective and inclusive engineering education programs that cultivate healthy and thriving engineering professionals.

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An asterisk (*) indicates the studies included in this scoping literature review.

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SUPPORTING INFORMATION

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APPENDIX

THE MAJOR MENTAL HEALTH FINDINGS OF THIS ScLR

Table A1 details the findings from each individual study included in this review, organized into the five major mental health categories (i.e., advisor relationship, cultural barriers faced by international students, gender and racial stereotypes, generalized findings, and social support and sense of belonging).

TABLE A1 Major mental health findings

Mental health measures and main findings (number of studies; %)	Study cited
Advisor relationship (9; 47%)	
Being provided opportunities and encouragement from an advisor can one see themselves staying in their field	1; Amon (2017)
Black students leaned into self-preservation coping strategies to combat feeling unwanted and unqualified to persist in their program; feelings fueled from interactions in their program with perceived belief in ability based on race; relationships perceived as a threat to success with minimal opportunities to improve or build the relationship	2; Burt et al. (2018)
Dissertation writing intervention helped overcome hurdles in asking advisor for help; students shared resistance in reaching out (e.g., feeling stuck or unsure what to write, uncertainty in advisors' response, difficulty communicating barrier)	3; Carter-Veale et al. (2016)
International students with perceived functional relationships were less likely to have used counseling or report an emotional/stress-related problem	7; Hyun et al. (2007)
Relationship was a source of stress and harm, with advisors being unsupportive and discouraging (e.g., being told they were incapable of doing doctoral work)	12; McGee and Bentley (2017)
Advisors vocalized expectation of no work-life balance (i.e., overwork oneself until physically/mentally drained); perceived biases in ability based on race (i.e., Asian peers viewed more capable); writer's block	13; McGee et al. (2019)
Faculty can promote positive well-being (e.g., sending an email of support, reframing struggles to reduce anxiety, validating students' struggles, confirming they belong); they can build trust by downplaying the gap between students and faculty; doctoral students viewed faculty as a last resort for support, fearing being viewed as incapable or lesser	15; Posselt (2018)
Although 94% of respondents did not anticipate changing advisors in the next 6–12 months, 24% would if able; of 230 international students, 94 indicated poor advising (e.g., inaccessible, lack of guidance, poor feedback, excessive demands), with 66 reporting concerns with their relationship (e.g., impersonal, unsupportive, disrespectful, abusive), 12 reporting a mismatch in research interests, and 21 reporting a lack of financial support	16; Rice et al. (2009)
International students' misalignment of research interests and mismatched expectations in advisor support and guidance leads to dissatisfaction	19; Zhou (2014)
Cultural barriers faced by international students (6; 32%)	
Although similar rates of self-reported emotional/stress-related problems (∼45%), international students are more likely to report financial problems, less likely to report relationship problems, and less likely to know about or use mental health resources.	7; Hyun et al. (2007)
Chinese international students perceived leisure activities as opportunities to relax, learn, and cope with pressure from their academic studies; leisure was often solitary or intended to further work-related goals due to the temporary nature of US student status; English culture and language limited social interactions and meaningful relationship building	8; Li and Stodolska (2006)
Chinese international students proposed to face acculturation stress; found reported higher levels of stress associated with lower reported well-being; basing self-worth on academic competence resulted in negative well-being when experiencing stress, suggesting self-blame; having higher levels of family recognition through achievement (importance of academic excellence to bring honor to family) had higher reported levels of well-being	9; Liao and Wei (2014)

TABLE A1 (Continued)

Mental health measures and main findings (number of studies; %)	Study cited
Chinese students are less likely to seek help for mental health concerns; turn to more culturally appropriate means for social–emotional support (i.e., friends or family), or hiding problems out of fear of worrying or disappointing them	14; Mikal et al. (2015)
Over a third of participants met cutoffs for clinically significant psychological distress; Chinese students reported significantly higher scores of acculturative stress (measured by societal, attitudinal, familial, and environmental factors) compared to Asian Indian students (thought due to Great Britain's colonization of home country lowering assimilation stress to western culture); higher levels of self-critical perfectionism linked to higher levels of depression; self-criticism and acculturative stress compounded on one another	17; Rice et al. (2012)
Unmet expectations (i.e., misalignment of research interests, advisor support and guidance, assumptions of graduate work, lack of social support) alongside a lack of mental and academic preparation lead to increased levels of dissatisfaction; students' motivated to persist due to interest in research, degree's high utility value, and fear/shame of quitting (e.g., high social cost, filial piety)	19; Zhou (2014)
Gender and racial stereotypes (6; 32%)	
Gender stereotyping limited females' professional development opportunities; experienced lowered levels of respect in leadership roles; motivations to work (i.e., desire for collaboration, social impact, self-development) challenged by barriers faced (i.e., lack of authority, the need for vigilance, gender stereotypes); needed buffers needed to cope (i.e., accomplishments, work-life balance), with social supports empowering resiliency	1; Amon (2017)
Black male engineering students experience discrimination from both gender and racially biased stereotyping from non-Black peers and faculty (i.e., belittling comments, lowered expectations/belief in abilities) fueled feelings of alienation, being unwanted, devalued, and unqualified; used self-preservation coping strategies to persist in toxic environments, often at the cost of their own health	2; Burt et al. (2018)
Black female engineering students experience structural racism and sexism (i.e., sexual harassment, abuse, hostile racial climate), contributing to racial battle fatigue, chronic stress, and feeling isolated; felt the need to prove themselves and require resiliency to persist	12; McGee and Bentley (2017)
Black doctoral students prioritized academic and career success over mental/physical well-being; pro-active coping mechanisms took a psychological, emotional, and physical toll (e.g., "push through" mentality); need to overcompensate work to combat gender and racial stereotypes; needed additional energy to survive day-to-day interactions, resulting in increased stress, role strain, performance anxiety, and doubt in academic abilities	13; McGee et al. (2019)
Having faculty of the same race and/or gender helped students come forward with experiences of sexual harassment and racial discrimination.	15; Posselt (2018)
African American students felt isolated and like second-class citizens; experienced racial profiling (i.e., police assuming not a student); assumed intellectually inferior; added strain to cope negatively affecting mental health	18; Torres et al. (2010)
Generalized findings (4; 21%)	
Comparing differences in academic performance; no gender differences in academic ability or perceptions of academic climate; women self-evaluated themselves to have lower levels of intelligence and reported significantly more stress longitudinally.	4; Cross (2001)
Being a woman or feeling insignificant in STEM settings predicted increased levels of distress; perceiving success relative to peers and positive perceptions of performance standards predicted increased well-being	6; Fisher et al. (2019)
Nationwide survey; engineering students reported the lowest help-seeking behaviors (master's 20.2%, doctoral 27.7%); 30.6% master's, and 26.2% doctoral students met the criteria for any self-reported mental health problem (e.g., depression, anxiety, suicidal ideation)	10; Lipson et al. (2016)
high performing students had high reported satisfaction with jobs, career trajectory and perceived success, and overall life satisfaction	11; Lubinski et al. (2006)

(Continues)

TABLE A1 (Continued)

Mental health measures and main findings (number of studies; %)	Study cited
Social support and sense of belonging (11; 58%)	
Social supports provided coping mechanisms and empowered resiliency for women graduate students and postdocs in STEM; lack of woman leader role models	1; Amon (2017)
Black male students felt unwanted in their program/department; felt isolated from others in the community (e.g., peers, advisors)	2; Burt et al. (2018)
Intervention targeting doctoral students' thesis completion and graduation; provided community, social support, and coping assistance; combatted feelings of isolation, writing paralysis, lack of directions or significant progress; helped with organization and setting measurable goals; incentivized to complete degrees on schedule	3; Carter-Veale et al. (2016)
Virtual discussion board supporting minoritized students in Bridge to Doctorate program; provided space to talk about concerns (e.g., benefits of a PhD, academia versus industry, HWIs versus HBCU, survival skills, fears, time management, research performance); fostered support, comradery, and a sense of belonging	5; Delaine and Fontecchio (2009)
Feeling accepted predicted increased well-being with a positive perception of departmental expectations lowering feelings of insignificance	6; Fisher et al. (2019)
Chinese international students with higher recognition of their achievements from their families had higher levels of well-being	9; Liao and Wei (2014)
Minorized students did not feel like they belonged; lack of peers and individuals to look up to (i.e., lack of faculty of color)	12; McGee and Bentley (2017)
Lack of Black faculty translated to minimal supports to turn to; did not feel belonging in engineering	13; McGee et al. (2019)
Chinese students turn to culturally appropriate means for social–emotional support (i.e., friends or family); online environment conducive to help-seeking with physical concerns (e.g., finding Chinese roommates, talking with other Chinese students in the United States)	14; Mikal et al. (2015)
Students are more likely to turn to peers, lab mates, and postdocs for support compared to faculty for fear of compromising their standing or being viewed as incapable	15; Posselt (2018)
African American students felt isolated and like second-class citizens; felt they did not belong and perceived by others as quota fillers	18; Torres et al. (2010)

Abbreviations: HBCU, historically Black colleges and universities; HWI, historically White institutions; STEM, science, technology, engineering, and mathematics.