Breaking the Stigma: Fostering Mental Health Resilience in Engineering—A Systematic Literature Review

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Abstract

The importance of students' mental health in the field of engineering education is becoming more widely acknowledged as a vital component affecting both academic achievement and general well-being. With an emphasis on undergraduate students, this systematic literature review (SLR) investigates the relationship between engineering education and mental health. Nineteen articles were chosen carefully, and once they were all examined, important topics and a summary of the literature were determined. Exam anxiety, social identities, and coping strategies, academic success, mental health identification and intervention, learning factors, and cognitive processes are just a few of the subjects that the SLR clarifies for engineering students. Five search phrases were used in this analysis: well-being + engineering, depression + engineering, anxiety + engineering, mental health + engineering, and mental illness + engineering. Seven databases were used, such as Google Scholar, Web of Science, IEEE Xplore, Engineering Village, ERIC, ScienceDirect, and Wiley Online Library, to examine these phrases.

Four themes emerged through the SLR: mental health identification and intervention, social identities and coping strategies, academic performance and test anxiety, learning factors and cognitive mechanisms. The research emphasizes the complexity of mental health problems faced by engineering students and the need for specific support systems and therapies. The findings highlight the significance of treating stress, anxiety, and depression in engineering students, and they offer suggestions for empowering them with useful coping mechanisms and customized support. The study also identifies areas in which further research is needed, such as the underrepresentation of specific demographic groups and the need for longitudinal techniques to fully understand the outcomes of lengthy treatments. The research summary emphasizes how important it is to give mental health in engineering significant importance instruction. In addition to achieving academic and professional success, students may promote healthy relationships and their general well-being by identifying and resolving mental health issues. The study ends by promoting evidence-based strategies to improve the cognitive and emotional aspects of student development, such as peer-led team learning and extensive support networks. Given the circumstances, this SLR offers a comprehensive viewpoint on mental health in engineering education, providing insightful information to practitioners, legislators, and academics to direct future initiatives fostering student well-being and academic success.

Keywords: anxiety, depression, engineering, mental health, mental illness, well-being

Introduction

In today's demanding academic setting, engineering students' mental health is vital [1]. The rigorous coursework, extended study plans, and elevated expectations might potentially be harmful to their psychological well-being [2]. It is important to understand that anybody may have mental health issues, including engineering students, and that seeking support is a sign of strength rather than weakness [3]. Maintaining excellent mental health requires many self-care practices, including regular exercise, a nutritious diet, getting enough sleep, and engaging in fun and stress-relieving activities [4]. However, because engineering school comes with a lot of duties, students could occasionally find it challenging to prioritize their health.

The expert assistance of mental health professionals, such as counselors or therapists, may be extremely beneficial to engineering students. These professionals can help students acquire coping skills. Strategies for burnout, stress, and anxiety, improving their mental health [5]. Additionally, practicing stress-reduction techniques like yoga, meditation, or mindfulness exercises can improve mental health and significantly reduce stress [6]. Maintaining mental health requires having healthy relationships with friends and family, and social support is crucial in this aspect [7]. To avoid feelings of loneliness and isolation, which may have a detrimental effect on mental health, engineering students need to actively seek out chances for social contact and engagement in extracurricular activities.

A SLR has been carried out to explore research on mental health in engineering education. This SLR study seeks to address the general research question, "What is the current state of, trends in, and directions for future research in mental health in the engineering of undergraduates?" by synthesizing previous studies and highlighting important themes. One of the objectives of this study is to highlight the need to make mental health a primary focus in engineering education. By recognizing and treating mental health concerns, students may enhance their overall well-being and foster healthy relationships, in addition to attaining academic and professional success [8].

Methods

The SLR process starts by entering various search terms into a variety of databases. A total of five search terms were used as a part of this examination: mental health + engineering, mental illness + engineering, depression+ engineering, anxiety + engineering, and well-being + engineering. The determination of search terms for the SLR is important for getting an exhaustive comprehension of the various parts of this topic. The expansive term "Mental Health + Engineering" serves as the foundational component, guaranteeing a comprehensive investigation of mental health issues in engineering education. By including "Mental Illness + Engineering", consider concentrating on analyzed mental well-being conditions, illuminating the commonness and effects of such afflictions among people in the engineering education space. The search terms "Depression + Engineering" and "Anxiety + Engineering" allow for a more detailed analysis of research on depression and anxiety disorders, respectively, in the engineering community. Finally, adding "Well-being + Engineering" offers a helpful viewpoint and seeks to identify protective variables and constructive treatments that contribute to the general mental health of engineers. These chosen search phrases, when combined, provide a comprehensive review of the literature, and capture the wide spectrum of mental health issues among engineering students. The databases used to find the articles were Google Scholar, Web of Science, IEEE Xplore, Engineering Village, ERIC (Education Resources Information Center), ScienceDirect, and Wiley Online Library. The SLR process and structure/format used in this paper was referred from several existing SLR studies [9-11].

Data Collection

Figure 1 shows the entire article selection process for the SLR. Items that met any of the seven exclusion criteria (EC) were excluded from consideration as they failed to meet the relevance of the study. Before full-text screening, the first five ECs were used. EC1) The articles published in languages other than English; EC2) The articles published before 2014 will be excluded (2014-2023); EC3) The articles without a focus on engineering will be excluded; EC4) The articles that do not directly focus on mental health (mental illness, depression, anxiety, well-being, and anxiety disorders) will be excluded; EC5) The articles that include both engineering and non-engineering student population. Afterward, the last two ECs were implemented after full-text screening. EC6)

Articles that do not have data will be excluded; EC7) Articles that focus on graduate students will be excluded. Initially, 3008 articles were retrieved using five search terms and seven databases. After completing the identification phase, duplicate articles from different databases were removed. Next, the initial screening of abstracts and, subsequently, full articles were screened to remove articles that were clearly identified as satisfying one or more of the exclusion criteria. Independent reviews were conducted before the remaining articles were included. In the end, the review's final synthesis phase contained 19 articles.

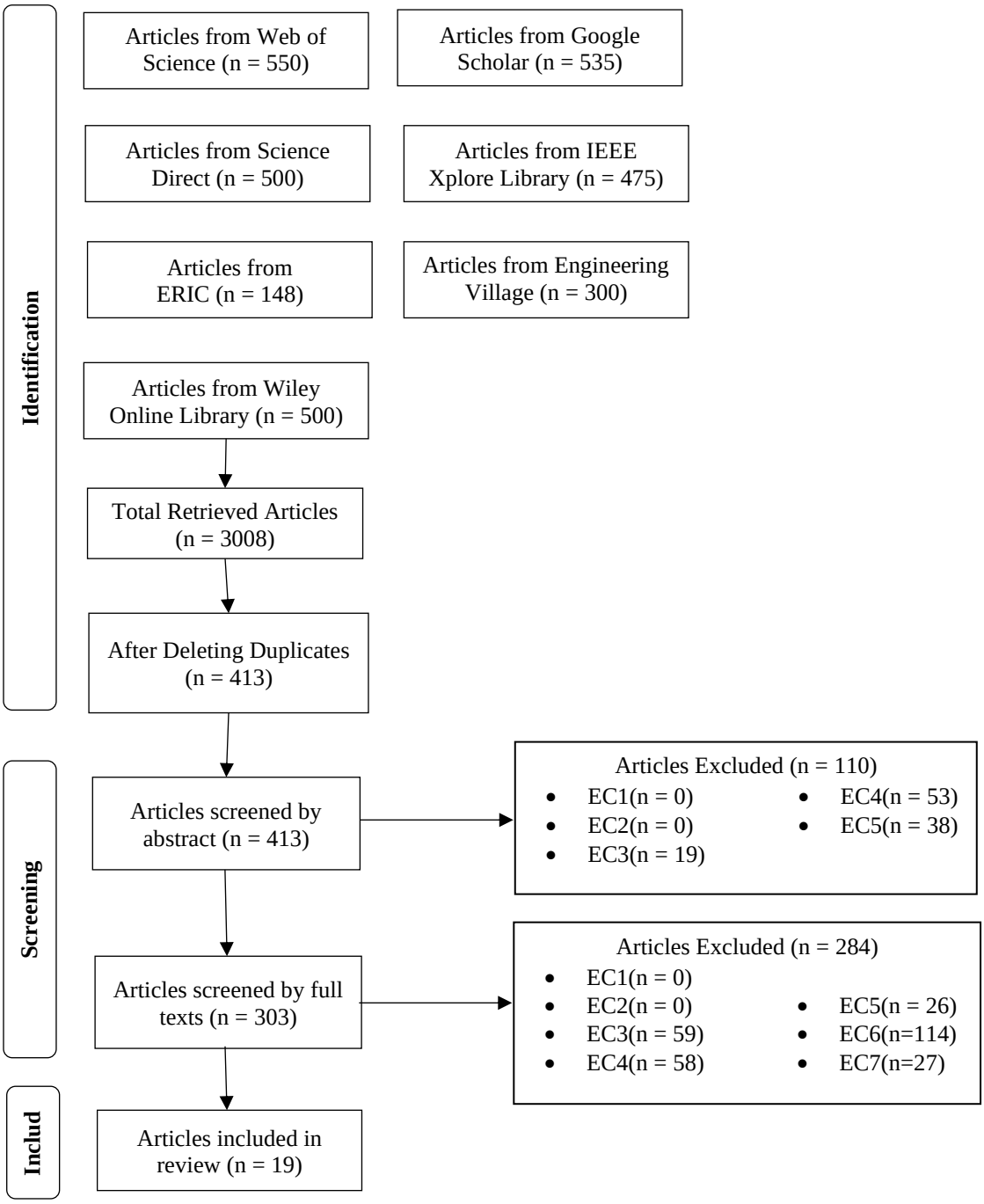

Figure 1: Systematic Literature Review – Article Selection Process

Data Analysis

After identifying the final 19 articles, a process was used to synthesize and interpret the publications. First, each article was read and summarized separately. For each article, the following information was recorded: year of publication, first author's country affiliation, research question, framework used, research design/methodology, data collection, sampling method and sample sizes, data analysis, findings, implications, future work, and important notes.

Codes describing common patterns across the nineteen articles were then created, along with a related codebook. There were 20 codes generated: Identification of Mental Health Population, Engineering Students' Mental Health Differences, Mental Health Wellbeing Research Designs, Interventions and Outcomes for Engineering Students, COVID-19 Impact, Screen Coping Intervention, Engineering Stress Social Identities, Inclusion and Engineering Identity Relationships, Screening Stress, Anxiety, Depression, Coping Strategies for Engineering Students, Stress Culture Relationships, Peer-Led Learning Social, Source Mitigation Strategies, Anxiety Assessment Mitigation, Interventions for Engineering Students' Academic Performance, Test Anxiety GPAs, Relationship between Test Anxiety and STEM Success, Cognitive Mechanisms in Information Integration, Statistics Test Anxiety Judgments, Peer-Led Learning Effect, and Info Integration Cognitive. The generated codes were then analyzed and grouped into four emergent themes: mental health identification and intervention, social identities and coping strategies, academic performance and test anxiety, learning factors, and cognitive mechanisms.

The data analysis in this paper is presented using descriptive statistics to examine trends in the nineteen articles chosen for further investigation. Then, a qualitative analysis of the nineteen articles across the four identified themes is discussed.

Strength and Limitations

This systematic literature review (SLR) evaluates the current state of knowledge and trends in the field to present a comprehensive picture of research on mental health among engineering undergraduates. Every theme from this study is supplemented by recommendations for practice and research intended to offer readers and/or researchers working in engineering education precise and useful directions. The study's conclusions significantly advance our knowledge of the state of the art regarding research on mental health in engineering education by assisting in the classification of the advantages of previous studies and the identification of potential areas for further investigation. There is no other recent SLR on the subject, according to our assessment of the literature. Like all studies, this one has its limitations. The articles were first selected based on exclusion criteria that lacked a metric for the information's quality or uniqueness. We hope that this limitation is lessened by using these distinct and extremely reputable databases. In line with other SLRs in engineering education, we used seven databases that we anticipated would contain numerous articles focused on mental health in engineering education research. The lack of books and other reports during the search process might have restricted the amount of material covered by the SLR. Second, the study's search terms concentrated on the relationship between engineering, mental health, and particular topic areas like anxiety and mental illness. Various word combinations containing these and other terms may have appeared in readings and discussions on mental health issues in engineering education. Third, the systematic review did not include any articles that were published after 2023. Furthermore, because some courses or programs that

practitioners and researchers may find interesting or relevant are still in the process of being published, this systematic review may only cover a portion of the landscape surrounding mental health in engineering education. Lastly, because the articles could only be found in English, it is possible that they only covered a small percentage of the worldwide research on mental health in engineering education.

Findings

First, we provide an overview of publication trends from 2014 to 2023. After that, we go into detail about each of the four themes that were found, offering descriptions, exemplar studies, and research and practice implications derived from an analysis of the final 19 articles. The year of publication, the nation of affiliation of the first author, the framework used, the research design and methodology, data collection, sampling method and sample sizes, data analysis, findings, implications, and future work are all described in the first section of our findings for the sampled articles. The second portion of our data provides a summary and classification of the study themes discovered in various articles.

Descriptive Findings Related to Publication Trends

Publications Per Year

The dataset covering the years 2014 through 2023 tells a powerful story of development and stability. Though there were none in the first half of 2014 and 2015, there was a notable increase in the following years. Remarkably, three instances in 2016 signaled the start of this increasing trend, suggesting a growing interest or involvement in the topic. From that point on, the trend remained mostly on the upward slope, with sporadic oscillations. There were notable surges in 2020, 2021, and 2022, with four and five occurrences, respectively, indicating a higher level of interest in or significance to the issue during those years. In years like 2017 and 2018, when the frequency of events declined a little, they were still there, which strengthened the ongoing interest in, or activity related to the topic. The topic's enduring relevance and solid foundation are suggested by its persistent appearance across time. All things considered, the data presents a picture of advancement and increasing significance, suggesting hope for the future. It portrays a changing scene in which interest in and significance for the subject matter remain within its pertinent domain. Such growth and stability are encouraging for future investigation, study, and advancement in the field that the data represents.

Country Affiliation of First Author

Table 1 demonstrates that the first authors from seven different nations were included in the articles chosen for this review. The United States accounted for 47.37% of the first authors, with India coming in second with 21.05%, Mexico with 10.53%, and all other countries with 5.26%. The results of the first authors' affiliation country distribution in the mental health field in engineering education research point to an American source for this kind of work. It is crucial to recognize any potential biases in these results. The inclusion criterion of articles written only in English is one significant factor that may distort the representation of nations and thus artificially increase the amount of research from the United States. Moreover, the apparent dominance of American research may not fully reflect the amount of funding or involvement that practitioners in other countries have given to research on mental health in engineering education. Diverse factors, such as different pressures, incentives, or infrastructure for research support, may impact the publication

patterns of researchers from different regions. For example, experts in other countries might actively engage in mental health education for engineers, but they might face barriers or have different priorities that prevent them from publishing. Therefore, the findings highlight the significance of American research in mental health in engineering education, but they also highlight the need for care in interpreting the data and recognizing any potential limitations before generalizing them to the field of mental health studies in engineering education. A more thorough understanding of the field can be attained by trying to diversify the representation of research and consider wider perspectives in subsequent analyses.

Table 1. Distribution of Countries of Affiliation of First Author

#	Country	Frequency	Percentage (%)
1	United States of America	9	47.37
2	India	4	21.05
3	Mexico	2	10.53
4	Nigeria	1	5.26
5	Philippine	1	5.26
6	Turkey	1	5.26
7	United Kingdom	1	5.26

Theoretical Frameworks

Nine out of the 19 sampled articles used particular theoretical frameworks to direct their research questions. These frameworks included a wide range of fields, such as cognitive science, educational pedagogy, social psychology, and mental health evaluation. Jensen and Cross's (2020) research, for example, explored Social Identity Theory (SIT) and how people's conduct is influenced by their group connections. The Depression, Anxiety, and Stress Scale (DASS) was used by Gedam et al. (2020) to measure psychological discomfort. Educational approaches like mastery-based education (MBE) as studied by MacFarlane et al. (2022) and peer-led team learning (PLTL) as examined by Eren-Sisman and Cigdemoglu (2018) were also common. Additionally, frameworks such as the Integrated Information Theory (IIT), Self-Regulated Learning (SRL), and Joanna Briggs Institute (JBI) provided academics with lenses through which to view awareness, learning strategies, and evidence-based healthcare practices, respectively. These frameworks served as invaluable tools, facilitating deeper insights into the phenomena under study and guiding potential interventions or policy recommendations within their respective fields.

Table 2. Theoretical Frameworks Used in Sampled Articles

#	Framework	Reference Articles
1	Social Identity Theory (SIT)	Jensen & Cross (2020)
2	Depression, Anxiety and Stress Scale (DASS)	Gedam et al. (2020)
3	Joanna Briggs Institute (JBI)	Tait et al., (2023)
4	Peer-Led Team Learning (PLTL)	Eren-Sisman & Cigdemoglu (2018)
5	Impact of Anxiety on Learning	Casinillo et al., (2022)
6	Integrated Information Theory (IIT)	Hedlefs-Aguilar et al., (2021) and Morales-Martinez et al., (2020)
7	Self-regulated learning (SRL)	Lee et al., (2020)
8	Mastery-Based Education (MBE)	MacFarlane et al. 2022

Research Foci and Research Methods

Table 3 provides a thorough summary of the study topics and approaches used in the sampled papers and provides insightful information about the wide range of scholarly research being conducted in the field. The study produced five separate research emphases, each of which shed light on a different aspect of academic performance, mental health, stress, and anxiety. Interestingly, a sizable fraction of the papers (36.84%) concentrated on determining the variables that affect stress and anxiety. To this end, a variety of research techniques were employed, such as descriptive-correlational designs, longitudinal studies, and both quantitative and qualitative analyses. Another popular area of research was academic performance, accounting for 26.32% of the articles. While some of this research included qualitative elements, the majority of these investigations used quantitative methodologies. Furthermore, a portion of the articles (15.79%) examined anxiety reduction techniques using cutting edge approaches like cognitive algebra and quasi-experimental procedures. Comparably, studies on self-reported mental health included 15.79% of the sampled papers and mostly used cross-sectional and quantitative methods. Moreover, one article (5.26%) that presented a descriptive synthesis of the body of knowledge already known in the topic was classified as a literature review. All things considered, this thorough analysis highlights the scope and depth of research projects meant to comprehend and tackle problems associated with stress, anxiety, and mental health, using a wide range of research approaches to increase understanding and guide therapies.

Table 3. Research Foci and Research Approach in Sampled Articles

#	Research foci	*N*	%	Research Methods	*N*	%	Sample size
1	Identify Factors Influencing Stress and Anxiety	7	36.84	Questionnaire Survey SPIRIT Program	3 3 1	15.79 15.79 5.26	20- 212
2	Academic Performance	5	26.32	Quantitative, Quantitative & Qualitative	3 2	15.79 10.53	15- 859
3	Evaluate Anxiety Reduction	3	15.79	Cognitive Algebra Quasi-experimental	2 1	10.53 5.26	140 - 474
4	Self-Reported Mental Health	3	15.79	Quantitative Cross-sectional	2 1	10.53 5.26	150 - 1173
5	Literature Review	1	5.26	No research (descriptive)	1	5.26	-

Thematic Analysis: Descriptions, Exemplars, and Implications

The four themes identified are examined in this section: mental health identification and intervention, social identities and coping strategies, academic performance and test anxiety, learning factors and cognitive mechanisms. We present two or more exemplary studies per theme, selected for their explicit focus on the subject as opposed to papers that only tangentially touched upon it, explain how the grouped articles relate to each other, and summarize the implications for future research and practice. The four themes are listed in Table 4 along with the number of mapped papers and the corresponding codes. Articles are mapped to themes in Appendix A; noticeably, a single article may be related to more than one theme. This organizes a thorough analysis that guides subsequent actions and summarizes recent research.

Table 4. Distribution of sampled articles based on thematic classification

Themes	**Definitions**	**Codes**	***N***
Mental Health Identification and Intervention	Topics pertain to understanding and addressing mental health. They involve identifying and recognizing disparities among student populations, designing effective research methodologies, implementing targeted interventions, assessing outcomes, examining the impact of COVID-19, and integrating coping strategies to promote mental well-being.	Identification of Mental Health Population, Engineering Students' Mental Health Differences, Mental Health Wellbeing Research Designs, Interventions and Outcomes for Engineering Students, COVID19 Impact, Screen Coping Intervention	7
Social Identities and Coping Strategies	Topics encompass the intricate dynamics of stress, social identities, and coping mechanisms within engineering education. They delve into understanding how social identities and inclusion intersect with engineering identity, screening for stress-related disorders, implementing coping strategies, examining the relationship between stress and engineering culture, fostering peer-led learning environments, and developing strategies to mitigate stress sources.	Engineering Stress Social Identities, Inclusion and Engineering Identity Relationships, Screening Stress, Anxiety, Depression, Coping Strategies for Engineering Students, Stress Culture Relationships, Peer-Led Learning Social, Source Mitigation Strategies	5
Academic Performance and Test Anxiety	Topics center around assessing and mitigating anxiety in engineering education contexts. They explore academic performance among engineering students under stress, analyzing test anxiety and their impact on GPAs, and investigating the relationship between test anxiety levels and success in STEM fields.	Anxiety Assessment Mitigation, Interventions for Engineering Students' Academic Performance, Test Anxiety GPAs, Relationship between Test Anxiety and STEM Success	8
Learning Factors and Cognitive Mechanisms	The topic revolves around cognitive processes and their effects on learning outcomes. They delve into understanding how cognitive mechanisms influence information integration, examining the impact of statistics test anxiety on cognitive judgments, assessing the effectiveness of peer-led learning approaches, and exploring the cognitive aspects of information integration in educational settings.	Cognitive Mechanisms in Information Integration, Statistics Test Anxiety Judgments, Peer-Led Learning Effect, Info Integration Cognitive	2

Theme 1: Mental Health Identification and Intervention

Each of the collected articles offers a distinct perspective on the mental health issues that students encounter, and together they contribute to the overarching theme of "Mental Health Identification and Intervention" in engineering education. This grouping seeks to provide a comprehensive understanding that covers external impacts such as the COVID-19 pandemic, coping strategies, and contributing factors. The intention is to highlight the need for specialized interventions and support while facilitating a nuanced understanding of the issues facing this population. Danowitz and Beddoes (2022) highlight the prevalence of major mental illnesses and the need for specialized resources by highlighting screening rates for these conditions among engineering students [12].

Jensen and Cross (2020) investigate the connection between stress, anxiety, depression, and engineering identity. They emphasize the value of inclusive cultures in maintaining mental health [13]. The investigation into the prevalence of stress, anxiety, and depression by Gedam et al. (2020), identifies academics as significant stressors and the possibility of performance-enhancing interventions [14]. In their scoping review of current interventions for engineering students' mental health and wellbeing, Tait et al., (2023) highlight a variety of strategies and results [15]. Exam stressors and associated coping strategies are examined by Balaji et al., (2019), emphasizing the impact of these factors on academic performance [13]. In their investigation of the COVID-19 lockdown's effects on engineering students' anxiety, Oyegoke et al. (2021) take gender disparities and coping mechanisms into account [17]. Lastly, Benitz et al. (2021) recommend customized support after comparing the effects of the pandemic on stress and anxiety in different genders [18]. When read as a whole, these articles allow for a nuanced examination of the issues surrounding mental health in engineering education, providing insightful information for educators, counselors, and legislators who are trying to promote the welfare of their students. They stress the importance of addressing key variables, giving students practical coping mechanisms, and offering specialized materials and interventions that are sensitive to newly emerging concerns like COVID-19. The crucial factors for the continuum of mental health identification through intervention are emphasized in this compilation of viewpoints.

Exemplar Studies: The two articles were chosen to emphasize the significance of giving mental health a top priority in engineering education and identification. The study by Danowitz and Beddoes (2022) highlights the mental health challenges faced by engineering students across eight U.S. institutions. Engineering students have higher rates of anxiety and depressive disorders, according to this study. Despite this, there is a sizable disparity between those who are probably having mental health problems and those who are seeking assistance. It was found that physical disability, gender, and ethnicity were significant predictors of positive mental health screen results, highlighting the importance of focused outreach and support. The results highlight how crucial it is to address disparities in mental health between demographic groups in engineering education to foster inclusivity and well-being [12]. The impact of stress on undergraduate students in the engineering culture is also examined by Jensen and Cross (2020). According to this study, there are significant gender and first-generation status differences in the elevated levels of stress, anxiety, and depression that engineering students self-report. The study highlights the importance of promoting inclusive cultures in engineering programs by finding links between engineering identity, perceptions of inclusion, and mental health symptoms. Higher levels of stress and depression were reported by female and first-generation students, highlighting the need for specialized support for these populations. To establish a supportive environment for everyone, the study advocates for a greater focus on mental health in engineering education [13].

Two articles that emphasize the critical significance of addressing mental health issues among engineering students are included in the category of exemplary studies under mental health intervention. According to Gedam et al. (2020), academic factors are major stressors for these students, who also frequently exhibit anxiety, depression, and stress. Task-oriented coping strategies highlight the need for customized interventions to improve mental health, which will improve academic achievement and institutional productivity. In addition to recommending methods such as biofeedback and mindfulness meditation, the study supports having faculty counselors to provide faculty members with focused support [14]. Tait et al. (2023) conducted a scoping review to emphasize the value of interventions in promoting good mental health and well-

being behaviors among engineering students. The research highlights the wide range of interventions that can successfully address stress, anxiety, and other mental health issues by identifying and mapping different evidence sources. Using a variety of outcome measures and quasi-experimental and quantitative designs emphasizes the need for a thorough and multidimensional approach. The primary findings of the study, which show gains in several areas, demonstrate how interventions may have a beneficial effect on motivation, communication, academic performance, and general psychological welfare. All these studies highlight how critical it is to give mental health care and interventions top priority in engineering education for the holistic well-being of students [15].

Research Implications: Future studies on "Mental Health Identification and Intervention" for engineering students should concentrate on the underrepresentation of racial and sexual identity groups to overcome the limitations noted in previous research [12-13] Scholars are urged to investigate alternative approaches to achieve more inclusive involvement and a more nuanced comprehension of a range of experiences. Furthermore, research by [14-15] highlights the importance of coping strategies and focused mental health interventions. Subsequent studies ought to probe further into the efficacy of said interventions, utilizing longitudinal methodologies to comprehend their enduring influence. The findings of Balaji et al., (2019) emphasize the importance of interventions that enhance the capacity for time management and problem-solving techniques, implying that long-term research may reveal their enduring impacts on the well-being of engineering students [16]. The impact of crises such as the COVID-19 lockdown on anxiety levels is brought to light by Oyegoke et al. (2021), highlighting the need for more research into the long-term effects on mental health and academic performance [17]. Finally, Benitz et al. study from 2021 on gendered experiences during the pandemic emphasizes the need for more data to be gathered to track changes in GPAs and evaluate long-term effects. This will help to enhance strategies for attracting and retaining a diverse pool of engineering students [18].

Practice Implications: For engineering students who want to prioritize and improve their mental health, the combined results of multiple studies on "Mental Health Identification and Intervention" provide insightful practical implications. A useful suggestion is to ensure that diverse racial and sexual identity groups are represented in talks and support programs to promote inclusivity in mental health discussions. This is based on the observations from [12-13]. Students can gain from actively participating in extensive mental health support programs offered by academic institutions, such as awareness campaigns, counseling services, and stress management workshops, according to research by [14]. Balaji et al., (2019) emphasize task-oriented coping mechanisms emphasizing the need to develop problem-solving skills and effective time-management techniques [15]. The insights provided by Oyegoke et al. (2021) regarding crisis-related anxiety highlight the importance of developing resilience and investigating coping mechanisms. These findings also provide helpful guidance for students who may be experiencing similar situations [17]. Finally, the gender-focused study by Benitz et al. (2021) highlights the significance of identifying and resolving gender-specific stressors and implies that both male and female students can profit from customized support measures. Together, these practice implications help engineering students maintain their mental health throughout their academic journey in a proactive and holistic manner and instructors can and should facilitate these discussions at the classroom and institution level [18].

Theme 2: Social Identities and Coping Strategies

The combination of the studies in this theme offers a comprehension of the complex interplay among social identities, coping mechanisms, and the mental health environment in the field of engineering education. Jensen and Cross's (2021) research highlight the marked disparities in mental health screening rates among engineering students, indicating greater susceptibility within specific demographic subsets [13]. Support systems should be specifically designed considering the importance of gender identity, ethnicity, and physical disabilities as critical variables affecting mental health outcomes. Adding to this, the research conducted in 2019 by Balaji et al., (2019) explores the stressors encountered by engineering students, revealing the interactions between coping strategies, environmental stressors, and academic variables.[16] In the context of engineering education, the emphasis on proactive coping strategies as vital to academic success creates a vital connection between stress management and general well-being. The novel Peer-Led Team Learning (PLTL) model is presented in Eren-Sisman and Cigdemoglu's (2018) work, which also clarifies how well it works to improve conceptual understanding and reduce anxiety in engineering students [19]. Building supportive communities within engineering programs is crucial, as evidenced by the focus on collaborative learning and the possible long-term advantages of such models. Yanik and Yan's (2016) study investigates anxiety-reduction strategies for engineering students to be proactive. The emphasis on identifying and reducing anxiety through group discussions and reflective practices highlights the significance of prompt and individualized support systems [20]. Peer-to-peer interactions and the sense of community arising from group discussions are crucial factors in creating an environment that supports mental health. Finally, the research conducted by Saranraj and Meenakshi (2019) broadens the discussion to include language learners and highlights the importance of motivational techniques, especially in the context of project-based learning (PBL). This study emphasizes the value of fostering inclusive, cooperative environments that reduce anxiety and improve skills [21]. Together, these studies support a comprehensive strategy that goes beyond conventional boundaries to address mental health in engineering education and develops students who are resilient, well-rounded, and successful in their careers. These studies' findings are consistent with the customized interventions, research-based teaching techniques, and community-building initiatives put forth [13][16][19-21].

Exemplar Studies: Together, these studies explore the nuanced terrain of mental health among undergraduate engineering students and social identities. The study conducted in 2021 by Jensen and Cross focuses on self-reported stress, anxiety, depression, engineering identity, and inclusion perceptions. The study reveals a higher-than-average prevalence of mental health issues, especially in female and first-generation students. It also emphasizes how important engineering identity and inclusive environments are in determining students' overall well-being [13]. The 2016 study by Yanik and Yan adopts a hands-on strategy by putting interventions in place to recognize and reduce anxiety in engineering students. The research tackles anxiety-inducing concerns like time management, degree completion, and post-graduation prospects through targeted interventions, journaling, and personal reflections. Taken together, these studies demonstrate how important it is to foster a mental health environment in engineering education through social identities, inclusive cultures, and practical anxiety-reduction strategies [20].

The study conducted in 2019 by Balaji et al. focuses greatly on the coping strategies used by undergraduate engineering and medical students when taking university exams. Examining stress, anxiety, and coping states, the study emphasizes that active coping techniques are more common

than avoidant coping. The results demonstrate how resilient and proactive the students were in handling their stress during difficult academic times. For creating focused interventions to assist students in navigating mental health issues, it is essential to comprehend the coping mechanisms employed by undergraduate engineering students, especially during exams. This study highlights coping states and their impact on academic achievement, providing valuable insights into stress management for engineering undergraduates to the larger discussion regarding mental health in educational environments [16].

Research Implications: These studies collectively offer valuable insights that recommend avenues for future research in the domain of engineering education, focusing on mental health and well-being. Jensen and Cross (2021) emphasize the necessity of investigating alternative research methodologies to obtain a more comprehensive comprehension of vulnerable demographic groups in the field of engineering [13]. To improve the generalizability of results, Balaji et al. (2019) work expands on this by recommending larger sample sizes and more comprehensive research projects that take cultural factors into account. Subsequent research endeavors ought to explore the diverse origins of stressors encountered by students, putting forth interventions that specifically target academic, environmental, and interpersonal stressors [16]. According to Eren-Sisman and Cigdemoglu's (2018) research, to promote both cognitive and affective development, evidence-based strategies such as Peer-Led Team Learning (PLTL) should be implemented. Future research could be directed to investigate gender disparities, compare studies with the general student population, broaden the scope of studies to include more diverse student populations and integrate longitudinal studies within scholar cohort [19]. The study by Yanik and Yan (2016) acknowledges the drawbacks of program specificity and short-term focus, and it calls for more research to examine the long-term impacts of mitigation strategies on success and anxiety [20]. To improve generalizability, they recommend comparative studies between various engineering programs that explore a range of anxiety sources, including socioeconomic factors. Encouraging future research to delve into the lasting impacts of motivational strategies, conduct comparative analyses across different contexts, and examine how individual and cultural variables influence language learners' achievements. By suggesting these lines of inquiry, we hope to add to a thorough research agenda that guides focused interventions and support networks, advancing the overall health of engineering education students [13][16][19-11].

Practice Implications: By utilizing the wealth of research on "Social Identities and Coping Strategies" in engineering education, practitioners can implement customized support networks and identify the unique stresses that different demographic groups encounter [13]. Active coping strategies include regular attendance, daily reading, physical exercise, and memory-enhancing practices [16]. Collaborative learning, modeled after the Peer-Led Team Learning (PLTL) model developed by Eren-Sisman and Cigdemoglu (2018), promotes a feeling of camaraderie and solidarity in engineering programs [19]. Inspired by Yanik and Yan's (2016) study, timely interventions, and reflective practices help people deal with anxiety by examining their fears and looking for support through group discussions [20]. Saranraj and Meenakshi (2019) state that employing a range of motivational strategies, participating in Project-Based Learning (PBL) activities, and giving back to supportive communities are all necessary for integrating motivational strategies and creating inclusive environments [21]. Through the implementation of these practices, students in engineering programs can develop positive mental health and effectively manage stress [13][16][19-21].

Theme 3: Academic Performance and Test Anxiety

With a primary focus on promoting mental well-being within the academic setting, the chosen articles collectively shed light on the relationship among engineering students between academic performance, test anxiety, and mental health. These studies highlight the critical relationship between academic achievement and mental health while offering a thorough examination of the many variables influencing success in STEM fields. In their investigation of the effects of test anxiety on first-year engineering students, Major et al., (2020) make the case for treatments that tackle systemic issues and suggest testing alternatives that put mental health above tradition [22]. Coop and Headley's (2021) research on the impact of distance learning on test anxiety in engineering undergraduates, looks at student feedback on experiences with distance learning, test anxiety, and academic achievement [23]. The project intends to provide insights into methods for promoting students' academic performance and mental health both during and after distance learning. The impact of pandemic-related learning experiences and socioeconomic factors on engineering students' anxiety levels when learning statistics is examined by Casinillo et al., (2022), underscoring the necessity of providing focused mental health support [24]. In their investigation of the cognitive processes underlying test anxiety assessments, Hedlefs-Aguilar et al., (2021) stress the significance of taking students' cognitive flexibility into account and its implications for mental health [25]. Sindhu's (2016) research on the connection between anxiety and academic performance emphasizes how important it is to create educational initiatives that improve students' mental health [26]. The study conducted by Hylton et al. (2017) examines the effects of active learning and flipped classroom pedagogies on motivation and design confidence, which can have a positive effect on mental health in the classroom [27]. The study by Lee et al., (2020) highlights the critical role that academic self-efficacy plays in fostering mental health and academic success by examining the relationship between test anxiety and academic self-efficacy as predictors of academic performance [28].

Exemplar Studies: The conclusions drawn from the two studies discussed in this section provide a vital direction for formulating approaches that tackle the substantial influence of exam anxiety on the mental health status of engineering students. Coop and Headley's (2021) study highlights the negative effects of exam anxiety on various undergraduate engineering students, especially in the context of distant learning. It demonstrates how test anxiety aggravates problems with study techniques, resource availability, and exam formats, especially for students from marginalized or underrepresented backgrounds. The study emphasizes the need for focused interventions to promote academic achievement and student well-being, particularly for female students who report greater anxiety levels [23].

Meanwhile, additional proof of the detrimental effects of anxiety on engineering students' academic achievement is provided by Sindhu's (2016) study, which emphasizes the need to address anxiety as a barrier to success. To enhance general wellness and academic accomplishment, this study highlights the need for mental health support services and treatments that reduce anxiety. All these results highlight how crucial it is to recognize and treat test anxiety in engineering education to create more welcoming and encouraging learning environments. By placing equal emphasis on mental health and academic performance, educators and professionals may better assist undergraduate engineers in overcoming obstacles [26].

Research Implications: The key findings of the cited studies point to several promising directions for future research in academic performance and test anxiety among engineering students. First,

research on the effects of testing culture would be beneficial in understanding the relationship between anxiety and academic success, particularly in underrepresented groups [22] Research topics that could be investigated include inclusive testing procedures and customized interventions. Examining the effectiveness of strategies derived from this information could be a beneficial research project. Furthermore, addressing factors that predict anxiety in online learning, such as subject difficulty, gender, and age (Casinillo et al. 2022), presents a chance for research to create and evaluate focused interventions [24]. Additionally, studies focusing on the cognitive processes that underlie test anxiety judgments have the potential to improve our knowledge and suggest interventions that support adaptive cognitive schemas [25]. Effective pedagogical strategies could be developed further by looking into the different effects of anxiety on academic performance in specialized engineering education settings and investigating long-lasting positive changes through a variety of instructional methods [27-28]. Finally, the notion that mastery-based learning can alleviate test anxiety (MacFarlane et al. 2022) necessitates further investigation into the long-term impacts of this approach, with an emphasis on reducing anxiety disparities and comprehending the qualitative elements that may contribute to its potential advantages for the general well-being and academic success of engineering students [29].

Practice Implications: Several useful conclusions can be made based on the understandings obtained from the examined research to help educators and engineering students promote academic achievement and good mental health. First, students who take proactive measures to address their test anxiety, like practicing mindfulness, creating study schedules, and reaching out to friends and family, stand to gain. It can be extremely helpful to establish a community of support where students feel comfortable sharing coping strategies and candidly discussing their fears. On the other hand, teachers can play a crucial role in reducing the reliance on traditional testing formats that may exacerbate anxiety by implementing a variety of assessment methods that accommodate diverse learning styles. Moreover, mastery-based education, as proposed by MacFarlane et al. (2022), can be explored as a potential substitute to reduce exam anxiety [29]. According to Hylton et al. (2017), involving students in active learning strategies may boost their self-esteem and drive [27]. As noted by Lee et al. (2020), instructors ought to think about including components that support academic self-efficacy, stressing the value of encouragement and positive reinforcement [28]. Furthermore, the findings from Casinillo et al. (2022) emphasize the importance of recognizing socioeconomic factors and experiences related to the pandemic, indicating the necessity for focused support initiatives [24]. Students and teachers alike can help create an environment in engineering education that is more welcoming, encouraging, and psychologically sound by accepting these useful implications.

Theme 4: Learning Factors and Cognitive Mechanisms

The research on Peer-Led Team Learning (PLTL) by Eren-Sisman and Cigdemoglu (2018) and cognitive mechanisms related to information integration by Morales-Martinez et al., (2020) come together to provide insightful knowledge about the complex interactions between cognitive and affective processes in learning environments. In an undergraduate engineering general chemistry course, Eren-Sisman and Cigdemoglu's (2018) research carefully compares the efficacy of PLTL to traditional college instruction, illuminating evidence-based teaching practices that impact both cognitive and affective aspects of student learning. The study acknowledges the complex interactions between cognitive and affective factors, especially when it comes to treating social anxiety, but it also highlights the positive effects of PLTL on conceptual comprehension and anxiety reduction [19]. Morales-Martinez et al., (2020) examine concurrently the cognitive

mechanisms that underlie engineering students' assessments of test anxiety, revealing the ways in which students utilize cognitive processes to gauge their anxiety levels before exams. This synthesis highlights the need for a thorough understanding of learning factors and cognitive mechanisms, as well as the holistic role that cognitive and affective factors play in forming the educational experience [30].

Exemplar Studies: The findings of these two studies highlight how important it is to integrate cognitive processes and learning variables when developing effective teaching tactics, especially when it comes to engineering students' mental health. The term 'learning factors' refers to the dynamic components that shape the educational environment, such as individual learner characteristics, instructional materials, learning environments, and teaching methodologies. Peer-led team learning (PLTL) is one example of an evidence-based teaching strategy that Eren-Sisman and Cigdemoglu (2018) highlight as being extremely important for improving both the learning process and the general wellbeing of STEM students. In addition to providing a comprehensive approach that addresses both the cognitive and affective aspects of student development, it highlights the transformative power of active and collaborative instructional methods [19].

Parallel to this, Morales-Martinez et al., (2020) investigate the complex field of 'cognitive mechanisms', examining the thought processes that underpin engineering students' assessments of test anxiety. Using integrative informational tool studies, this study reveals the complex ways in which students interpret information in academic assessment scenarios as well as the key variables influencing test anxiety. This deep understanding proves instrumental in crafting strategies that specifically target cognitive processes, aiding students in managing evaluative anxiety and fostering their overall mental well-being [30].

When taken as a whole, these studies highlight the multidisciplinary nature of successful education and the mutually beneficial relationship between internal cognitive processes and external learning variables. For example, PLTL integrates evidence-based teaching methodologies. When combined with a thoughtful understanding of the cognitive processes associated with test anxiety, these approaches greatly enhance the development of learning environments that are impactful and supportive for engineering students. This all-encompassing educational approach addresses mental health issues in the engineering field while acknowledging the nuances of information presentation and cognitive engagement. It presents a comprehensive plan to improve the educational experience.

Research Implications: The theme of 'Learning Factors and Cognitive Mechanisms' emerges with implications for improving mental health in engineering education, synthesizing insights from the studies by Eren-Sisman and Cigdemoglu (2018) and Morales-Martinez et al., (2020). Future directions for research include examining the particular elements of the Peer-Led Team Learning (PLTL) model to identify variations in its application, which will provide educators important information for improving their teaching methods. Conducting longitudinal research to monitor the long-term impacts of project-based learning on students' emotional and cognitive health may provide insight into the long-term advantages of applying evidence-based practices in STEM education. Later research could explore methods to enhance group dynamics to tackle social anxiety in PLTL teams. They might also investigate the value of cultivating inclusive environments and leadership skills. Furthermore, given the dynamic nature of the digital environment, scholars may investigate the incorporation of technology in PLTL sessions and evaluate the effects of virtual collaboration tools on emotional stability and cognitive

comprehension [19]. Further research could broaden the focus of the cognitive mechanisms underlying test anxiety by investigating additional factors that impact cognitive processes, building on the findings on the study by Morales-Martinez et al., (2020). It is essential to use qualitative approaches to learn about students' opinions regarding the efficacy of PLTL and test anxiety interventions. To address the relevance of effective course design in both face-to-face and online modalities, it is also necessary to look at the skill sets required for effective online instruction and strategies to adapt curriculum design to online formats. To address the relevance of effective course design in both face-to-face and online modalities, it is also necessary to look at the skill sets required for effective online instruction and strategies to adapt curriculum design to online formats. In an all-encompassing and student-centered educational approach, these research directions seek to promote evidence-based practices that improve cognitive understanding and support engineering students' mental health and well-being [30].

Practice Implications: The implications presented in this section have applications that provide educators and practitioners with doable tactics to enhance the mental health and overall well-being of engineering students. According to Eren-Sisman and Cigdemoglu (2018), adopting evidence-based practices—particularly peer-led team learning (PLTL), is necessary to support both cognitive and affective development. Instructors should intentionally encourage inclusive group dynamics within PLTL teams and the growth of leadership abilities to lessen social anxiety [19]. Morales-Martinez et al., (2020) propose that emotional well-being and cognitive comprehension can be enhanced in the context of online learning through the thoughtful integration of technology. Extended positive effects can result from long-term engagement strategies with PLTL that are in line with the research findings about their enduring effects. Comprehensive support that considers a person's learning preferences and socioeconomic background is necessary to address test anxiety. Consistently requesting feedback from students and utilizing qualitative approaches guarantees that continuous enhancements are in line with their preferences and experiences. Finally, instructors should modify their curricula to accommodate online learning, taking into account the insights that Morales-Martinez et al., (2020) have provided regarding the necessary skill sets [30]. By putting these strategies into practice, instructors can help engineering students learn in a nurturing and psychologically sound environment.

Conclusion

With an emphasis on undergraduate students, this systematic literature review provides a thorough investigation of the relationship between mental health and engineering education. This review offers important insights into a number of mental health-related topics, such as identification, intervention, social identities, coping strategies, academic performance, test anxiety, learning factors, and cognitive mechanisms. It was achieved through a rigorous selection process and analysis of 19 articles. The synthesis of research highlights the complexity of mental health issues that engineering students confront and stresses the value of specialized support networks and interventions. The review highlights certain gaps in the literature, including the underrepresentation of particular demographic groups in studies on mental health and the necessity of longitudinal methods to comprehend the long-term effects of interventions.

The combined studies highlight a number of significant themes, such as the significance of treating stress, anxiety, and depression in engineering students, the function of coping mechanisms and social identities in mental health, and the effect of test anxiety on academic achievement. Additionally, the review underscores the efficaciousness of interventions like mindfulness

practices and peer-led team learning in augmenting the cognitive and affective aspects of student development. Future studies should concentrate on filling in the gaps that have been found, looking into creative ways to promote mental health in engineering education, and examining the long-term effects of interventions. Instructors and legislators can support the academic success of engineering students and their overall well-being by implementing evidence-based practices and creating inclusive environments.

In summary, this study offers a thorough analysis of the literature on mental health in engineering education, covering works written between 2014 and 2023. Using five search terms, 3008 articles were found in seven databases; 19 of those were synthesized. The four themes that resulted from their synthesis were as follows: mental health identification and intervention, social identities and coping strategies, academic performance and test anxiety, learning factors and cognitive mechanisms. For every theme, two or more exemplary studies were presented along with research and practice implications.

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APPENDIX A: Categorization of the examined article according to the theme

Theme 1: Mental Health Identification and Intervention

Authors	*Country affiliation of first author*	*Title*
Danowitz and Beddoes	United States of America	Mental Health in Engineering Education: Identifying Population and Intersectional Variation
Jensen and Cross	United States of America	Engineering stress culture: Relationships among mental health, engineering identity, and sense of inclusion
Gedam, Saklecha, and Babar	India	Screening of stress, anxiety, depression, coping, and associated factors among Engineering students
Tait, Alexander, Hancock, and Bisset	United Kingdom	Interventions to support the mental health and wellbeing of engineering students: a scoping review
Balaji, Murthy, Naveen Kumar, and Chaudhury	India	Perceived stress, anxiety, and coping states in medical and engineering students during examinations
Oyegoke, Olotu, and Ojetunde	Nigeria	Impact of COVID-19 lockdown policy on the anxiety of the engineers-in-training in ABU Zaria Engineering Faculty in Nigeria
Benitz, Jeznach, and Conrad	United States of America	Understanding the Impacts of COVID-19 on Feelings of Stress and Anxiety in Women Engineering Students

Theme 2: Social Identities and Coping Strategies

Authors	*Country affiliation of first author*	*Title*
Jensen and Cross	United States of America	Engineering stress culture: Relationships among mental health, engineering identity, and sense of inclusion
Balaji, Murthy, Naveen Kumar, and Chaudhury	India	Perceived stress, anxiety, and coping states in medical and engineering students during examinations
Eren-Sisman and Cigdemoglu	Turkey	The effect of peer-led team learning on undergraduate engineering students' conceptual understanding, state anxiety, and social anxiety

Yanik and Yan	United States of America	Sources of Anxiety among Engineering Students: Assessment and Mitigation
Saranraj and Meenakshi	India	Influence of Motivation Factor and Anxiety in L2 Learning among Engineering Students in Dharmapuri, India

Theme 3: Academic Performance and Test Anxiety

Authors	*Country affiliation of first author*	*Title*
Major, Scheidt, Godwin, Berger, and Chen	United States of America	Effects of Test Anxiety on Engineering Students' STEM Success
Coop and Headley	United States of America	Test Anxiety and Its Impact on Diverse Undergraduate Engineering Students During Remote Learning
L. Casinillo, Lina Jr, F. Casinillo, Batidor, and Lebante	Philippine	Econometric Evidence on Statistical Anxiety of Engineering Students during the New Normal Setup
Hedlefs-Aguilar, Morales-Martinez, Villarreal-Lozano, Moreno-Rodriguez, and Gonzalez-Rodriguez	Mexico	Functional Measurement Applied to Engineering Students' Test Anxiety Judgment for Online and Face-to-Face Tests
Sindhu	India	Impact of Anxiety on Academic Achievement among Engineering Students
Hylton, France, and DiBerardino's	United States of America	Impact of Various Pedagogies on Design Confidence, Motivation, and Anxiety of First-Year Engineering Students
Lee, Rhoads, Berger, and DeBoer	United States of America	WIP: The Predictive Power of Engineering Undergraduate Students' Academic Self-efficacy and Test Anxiety for Their Academic Performance in a Dynamics Course
MacFarlane, Piercy, Hachten, Atwood	United States of America	Mastery-Based Course Design Reduces Exam Anxiety in Undergraduate Engineering Students

Theme 4: Learning Factors and Cognitive Mechanisms

Authors	*Country affiliation of first author*	*Title*
Eren-Sisman and Cigdemoglu	Turkey	The effect of peer-led team learning on undergraduate engineering students' conceptual understanding, state anxiety, and social anxiety
Morales-Martinez, Garcia-Collantes, Hedlefs-Aguilar, Charles-Cavazos, and Mezquita-Hoyos	Mexico	Information Integration Cognitive Mechanisms Underlying the Face-to-Face or Online Statistics Test Anxiety Judgments of Engineering Students