Examining STEMM Mentorship within Student Organizations in Higher Education through a Critical Lens

Abstract

In this critical theory review paper, the researcher seeks to 1) reveal the current landscape of the research literature on science, technology, engineering, mathematics, and medicine (STEMM) mentorship that occurs within student organizations at institutions of higher education, 2) determine if the mentorship described in these articles exemplify critical mentorship as defined in the literature, and 3) determine if the addition of critical mentorship components adds value, defined here as a *synergistic effect*, for STEMM students who serve as mentors or mentees through their student organizations. As the intersection of STEMM mentorship and student organizations at institutions of higher education remains underrepresented in the literature, this paper also highlights the need for more studies in this area.

Mentorship is an important topic in STEMM education due to its role in a student's professional formation. Defined as "a professional, working alliance in which individuals work together over time to support the personal and professional growth, development, and success of the relational partners through the provision of career and psychosocial support," mentorship may "enhance student outcomes, experiences, and retention" and "help with workforce development by increasing access, equity, and inclusion in STEMM" [1]. A mentorship relationship can last anywhere from three months to a lifetime and is most effective when critical theories are applied to mentoring practice [1], [2]. Practicing critical mentorship, however, requires that social constructs, such as race, gender, and socioeconomic status, be examined through a critical lens such that the mentorship relationship is "at once reciprocal, collaborative, participatory, emancipatory, and transformative" [2]. Involvement with student organizations has been shown to have a positive effect on student success, especially for students from historically marginalized communities (HMC) [3]. STEMM mentorship that occurs through student organizations should, therefore, have a synergistic effect.

A three-stage methodology was utilized: 1) Components and activities related to mentorship, referred to here as *mentorship indicators*, were extracted from the relevant literature and a thematic codebook was developed. 2) A scoping review of the literature was conducted to identify articles related to STEMM mentorship in student organizations in higher education. 3) Using the codebook developed in stage 1, reflexive thematic analysis was conducted on articles selected in stage 2.

The findings presented answer the following questions: 1) What is the current landscape of the research literature on STEMM mentorship that occurs within student organizations at institutions of higher education?, 2) Does the mentorship described in these articles exemplify critical mentorship as defined in the literature?, and 3) Does the addition of critical mentorship components have a synergistic effect for STEMM students who serve as mentors or mentees through their student organizations? While this review is laser-focused on STEMM mentorship that occurs within student organizations at institutions of higher education, it will lay the groundwork for future work on the role critical mentorship plays in the professional formation of STEMM students, regardless of their level of education.

Keywords: critical mentorship, STEMM, post-secondary students, student organizations

1. Introduction

Mentorship is an important topic in STEMM education due to its role in a student's professional formation. Defined as "a professional, working alliance in which individuals work together over time to support the personal and professional growth, development, and success of the relational partners through the provision of career and psychosocial support," mentorship may "enhance student outcomes, experiences, and retention" and "help with workforce development by increasing access, equity, and inclusion in STEMM" [1]. A mentorship relationship can last anywhere from three months to a lifetime and is most effective when critical theories are applied to mentoring practice [1], [2]. Practicing critical mentorship, however, requires that social constructs, such as race, gender, and socioeconomic status, be examined through a critical lens such that the mentorship relationship is "at once reciprocal, collaborative, participatory, emancipatory, and transformative" [2]. Involvement with student organizations has been shown to have a positive effect on student success, especially for students from historically marginalized communities (HMC) [3]. STEMM mentorship that occurs through student organizations should, therefore, have a synergistic effect.

2. Research Questions

This study seeks to answer the following research questions:

1) What is the current landscape of the research literature on STEMM mentorship that occurs within student organizations at institutions of higher education?

2) Does the mentorship described in these articles exemplify critical mentorship as defined in the literature?

3) Does the addition of critical mentorship components have a synergistic effect for STEMM students who serve as mentors or mentees through their student organizations?

3. Methodology

A three-stage methodology was utilized: 1) Components and activities related to mentorship, referred to here as *mentorship indicators*, were extracted from the relevant literature and a thematic codebook was developed. 2) A scoping review of the literature was conducted to identify articles related to STEMM mentorship in student organizations in higher education. 3) Using the codebook developed in stage 1, reflexive thematic analysis was conducted on articles selected in stage 2.

3.1 Identification of Mentorship Indicators from the Relevant Literature

The researcher consulted with several mentorship content matter experts to gather their thoughts on the topic and obtain recommendations on literature discussing mentorship indicators. From there, the researcher sought out additional literature. After having read and reflected on the information, the researcher constructed a draft conceptual framework for the purposes of

categorizing and conceptualizing the types of mentorship, including traditional, effective, and critical mentorship, as well as identifying the relevant mentorship indicators associated with these mentorship types.

3.2 Scoping Review

For this study, a scoping review protocol based on Arksey and O'Malley's framework [4] was utilized as described previously [5]. Scoping reviews are useful when probing the literature as they emulate the rigor of systematic reviews while keeping laser-focused on answering the research questions [4], [5]. Scoping reviews are most effectively conducted using a team approach [6]. The review team for this study consisted of a researcher with experience conducting scoping reviews and two content matter experts. The review team had weekly check-ins throughout the scoping review process, as is recommended in the literature [6].

Search Strategy: Web of Science and Scopus were selected as the most appropriate databases for the literature search due to their robust query tools [7]. Both databases were searched on October 10, 2023, using the search string shown in Table 1, below:

Table 1. Initial search string

Topic	**Search Terms**
Mentorship	ALL (mentor OR mentors OR mentee OR mentees OR mentorship OR mentoring)
	AND
Student organizations	ALL ("student organization" OR "student organizations" OR "student group" OR "student groups" OR "student club" OR "student clubs")

This search string was created with the help of a university librarian and purposefully made to be very broad in scope. This decision was based on the desire to avoid excluding pertinent articles that may use different terminology but refer to the same concepts of interest.

Screening Process: The inclusion and exclusion criteria shown in Table 2, below, were used for the screening process:

Table 2. Final inclusion and exclusion criteria.

Inclusion Criteria	**Exclusion Criteria**
English language	Not in English
Higher education	Not higher education
Primary research	Not primary research
Indexed in Web of Science or Scopus	Not a journal article
Mentorship in student organizations	No mention of mentorship No mention of student organizations

To exclude non-English articles, a database query tool that filters by language was used to limit search results to articles written in English. Only journal articles were desired for this search; since only journal articles should be indexed by Web of Science or Scopus, this criterion was met by searching those two databases [7]. To ensure that nothing accidentally slipped through the cracks, this criterion was still used for manual screening. After database searches were conducted as described, all resulting articles were exported as RIS files. RIS is a standardized file format that allows for the transfer of tagged citation data between reference management systems [8]. The RIS files were then imported into the cloud-based systematic review software Covidence [9]. Covidence was used as it simplifies the review process and increases rigor [10]. The screening process occurs in two stages wherein articles are presented at random. During the first stage, the Title and Abstract Screening, articles are presented with their titles and abstracts visible. Individual articles can be designated as yes, maybe, or no, with yes meaning it meets the inclusion criteria and no meaning it meets one or several exclusion criteria. In this view, articles can also be given notes or tags, which make it easier to track reasons for exclusion later on.

The criteria related to higher education, primary research, and mentorship in student organizations were identified through the screening process. To speed the screening process, Covidence provides a highlight tool for keywords that highlight user-defined terms. Keywords included: “mentor”, “mentoring”, “mentorship”, “mentee”, “student”, “organization”, “group”, and “club”. For the higher education criterion, if the title or abstract of an article stated that it was focused on middle school students, for example, it was marked for exclusion. Similarly, if an article had “review” in the title or abstract, or was otherwise described as a review article, it was excluded. Articles that mentioned mentorship, mentors, or mentees and mentioned student organizations, student groups, or student clubs were included, and moved into the full-text screening stage. Any articles for which this particular criterion was unclear were designated as a “maybe” and moved into the full-text screening as well.

The second stage of the Covidence screening process is the Full-Text Screening. Before performing this screening, PDFs of all articles needed to be uploaded to Covidence. Some citation data for articles at this stage were already associated with PDFs. The process of locating, downloading, associating, and uploading the remaining PDFs was simplified through the use of Covidence’s Bulk Upload Tool and the open-source reference manager Zotero [11]. Once citation data was imported into Zotero, the Find Available PDF’s feature was used to automatically download and associate many PDFs. The few PDFs that were still missing after using this feature were manually downloaded, associated with citation data, and uploaded to Covidence.

For the Full-Text Screening, articles were presented at random, and the PDF files were opened and read through to determine if the mentorship discussed in the article occurred in, was facilitated by, or was associated with a STEMM student organization. Those articles which did not fit that criterion were marked for exclusion with the reasoning that “mentorship within the context of student organizations is not discussed”. Articles that did meet this criterion were moved into the Data Extraction phase.

Data Extraction: For the Data Extraction phase, Covidence lists articles at random and displays a data extraction template side-by-side with each individual article when selected. This template can be edited by the reviewer for relevance. Reviewers should take care to only extract relevant data

during a scoping review [6]. In this case, the data points for extraction were the Title, Country, Year, Journal, STEMM Field, and the Type of Mentorship exhibited in the article.

Descriptive Analysis: All articles excluded during the Title and Abstract Screening were categorized by Covidence as Irrelevant. Citation data for all Irrelevant articles was exported from Covidence as a CSV file. Notes and tags added during the screening process were included. The CSV file was opened with the productivity software Microsoft Excel and was saved as an Excel file format (.XLSX) spreadsheet. A sheet was added to this spreadsheet to serve as a tag counter; the tags and Covidence numbers of all Irrelevant articles were copied over into this sheet. Utilizing the Excel formulas COUNTIF and SUM, all instances of the various reasons for exclusion were tabulated and summed. A similar process was done for the extraction data in order to tabulate and sum the various data points collected.

3.3 Reflexive Thematic Analysis and Thematic Coding

In this study, the researcher utilized reflexive thematic analysis [12], [13], [14], [15] to engage critically with the articles identified through the scoping review process towards an improved understanding of STEMM mentorship in student organizations in higher education.

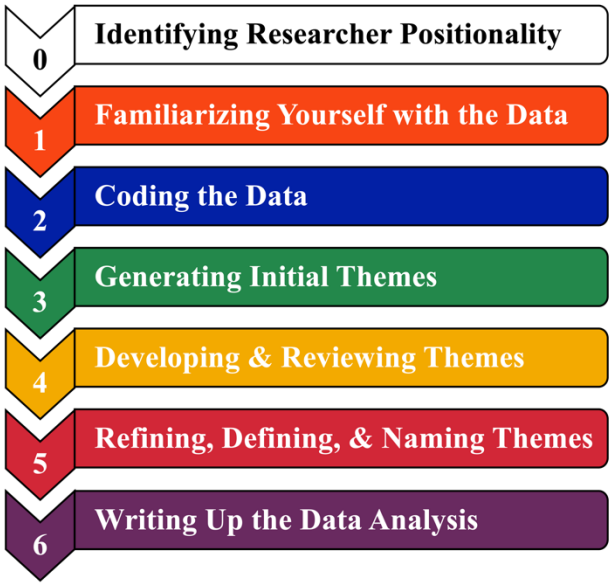

Figure 1. Phases 1 – 6 of the RTA process [12], with the addition of Phase 0

Reflexive thematic analysis (RTA) is a powerful, "theoretically flexible" approach to thematic analysis first developed by Braun and Clarke in 2006 for "qualitative research in and beyond psychology" [13]. Doing RTA requires one to critically reflect on their role as researcher [12], which includes how their positionality factors into their research practice and research process [12], [14]. RTA has six phases [12], [13], as shown in Figure 1 to the left. RTA relies heavily on the researcher's interpretation, a stance that rejects the positivist notion of researcher bias and instead embraces the researcher's positionality as a qualitative research tool [14]. This necessitates that researchers practice reflexivity and identify their positionality before conducting RTA [15].

Reflexivity refers to "critically interrogating what we do, how and why we do it, and the impacts and influences of this on our research" [12]. It is notable that RTA does not usually involve validation steps, however, when working with focus group or interview data, participant checking can be done to enhance credibility [16] and ensure that the participants' sentiments were captured accurately [14]. For this study's purposes, the researcher incorporated an additional phase to account for the prerequisite evaluation and declaration of the researcher's positionality, referred to as Phase 0.

3.4 Description of RTA Stages Used in this Study

Phase 0. Identifying Researcher Positionality: Since qualitative research orients the researcher as both the instrument through which data is collected and the one responsible for conducting data analysis, it is of utmost importance that qualitative researchers take positionality into consideration while designing and conducting their work [17]. While positionality may be a new concept to engineering education researchers who were exclusively trained in quantitative research methods [18], it has recently been shown to "impact six fundamental aspects of research: research topic, epistemology, ontology, methodology, relation to participants, and communication" in engineering education research [19]. Though this process can be time-consuming [20], successful completion of Phase 0 is essential to producing high quality RTA results as result quality relies upon the researcher's understanding of their own perspectives and subjectivity [12]. It is also important to recognize that this reflexive process of understanding oneself is never truly completed and new insights may emerge at any point in time [12].

Phase 1. Familiarizing Yourself with the Data: Phase 1 has three stages [12]. Stage 1 requires that ample time be allocated towards *immersion in the data*, which will necessitate reading through the content of the data until the researcher has reached saturation. Stage 2 requires critical engagement with the data by asking reflexive questions. Stage 3 involves documenting answers to the questions posed during stage 2 and capturing other thoughts and feelings about the data.

Phase 2. Coding the Data: Phase 2 involves the systematic interrogation of the data; once relevant segments are found, they are highlighted, categorized, and described [12]. This process is referred to as *coding* and is meant to apply insight and rigor to the analysis [12]. Coding results in *codes*, each of which should capture different meanings. In RTA, it is customary for the coding process to include only one coder and for them to not be guided by a codebook or framework; this paints RTA in contrast with other forms of thematic analysis, such as intercoder reliability thematic analysis, which utilizes multiple coders who are all guided by the same codebook [21]. The actual process of coding may take several rounds and evolve over time as the researcher's "analytic insight develops" [12].

Phase 3. Generating Initial Themes: Phase 3 involves the organization of codes into potential themes based on patterns of shared meaning across the dataset [12]. Many potential themes may be generated at this time, but only two to six will ultimately prevail in most cases [12]. Drawing thematic maps can help to conceptualize potential themes and their relationships with one another. There are three possible levels to theming in RTA: overarching concepts, themes, and subthemes.

Phase 4. Developing and Reviewing Themes: In Phase 4, the initial themes are checked for relevance and applicability to the research questions [12]. This is an iterative process and may require some themes to be redeveloped (e.g. might have to move back into Phase 3) [12]. First, potential themes are reviewed against the groups of codes to check if they make sense for each code they are meant to represent. Next, themes are checked for clarity, coherence, and importance in terms of the data and research questions. Finally, themes are compared against the whole dataset to ensure that each theme works as it should.

Phase 5. Refining, Defining, and Naming Themes: In Phase 5, themes are tested to ensure that they center meaning-making [12]. Themes must be sufficiently rich and informative to fully capture the concepts they represent. Writing an abstract or definition for each theme can assist in their elimination or retention [12]. After testing, themes are named using short phrases that evoke their "meaning and analytic direction" [12].

4. Results and Discussion

4.1 Scoping Review

After searching the two databases, 733 articles were found on Scopus and 397 articles were found on Web of Science, for a total of 1,130 articles. After duplicate removal, 1,078 articles remained. The remaining articles were screened sequentially using Covidence. First, titles and abstracts were read to determine if the three major inclusion criteria were met, namely: mention of mentorship and a student organization in higher education. 1,032 articles were deemed to be irrelevant after the title and abstract screening was completed. This is summarized in Table 3, below:

Table 3. Reasons articles were deemed irrelevant, multiple reasons possible

Exclusion Criteria Met After Abstract and Title Screening	***n***
No mention of student organizations	951
No mention of mentorship	632
Not higher education	202
Not primary research	37
Not a journal article	3
Total	1825

Next, the full text of the remaining 46 articles were read to assess eligibility. For an article to be considered eligible, the aforementioned mentorship must have occurred in, been facilitated by, or been associated with a STEMM student organization. After this screening process was completed, 20 articles [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55] were deemed relevant to the study and marked for inclusion in the review. This process is summarized in Figure 2, on the following page.

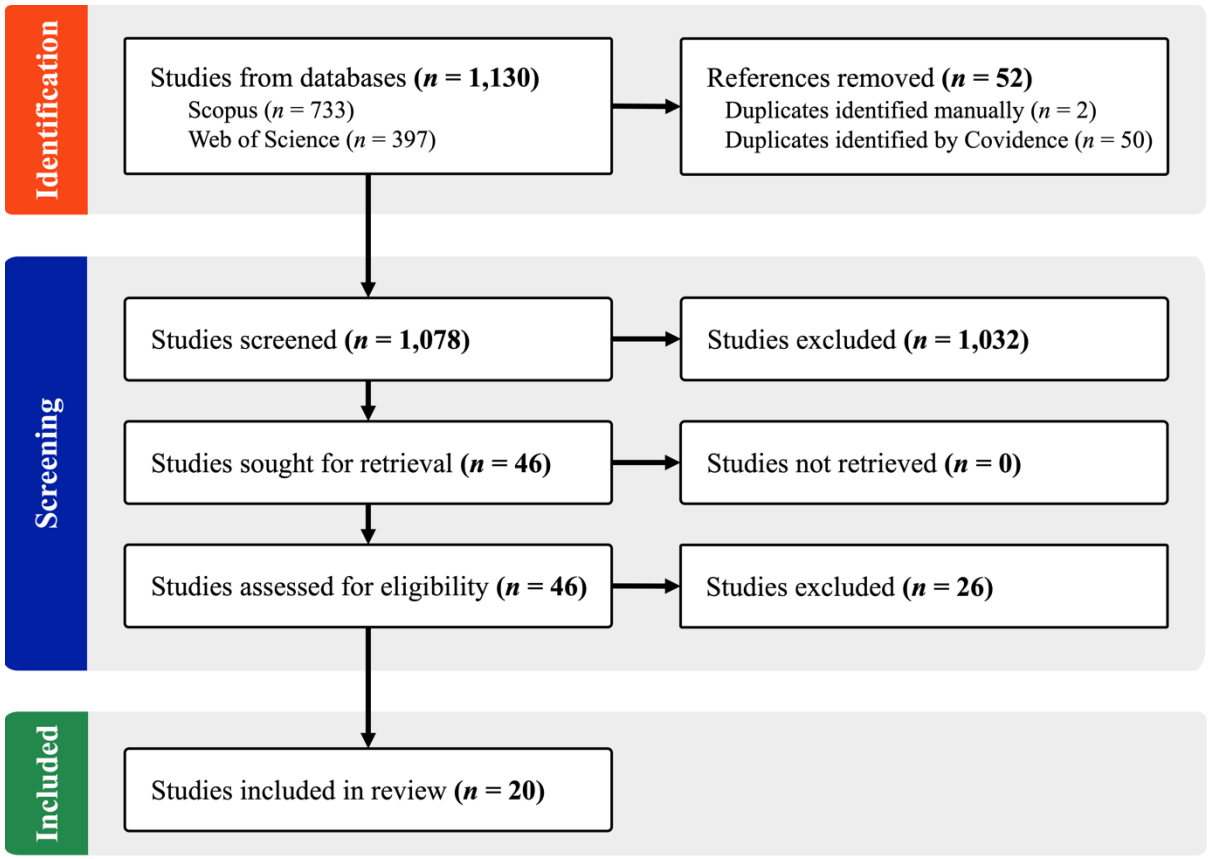

Figure 2. PRISMA flow diagram; template exported from Covidence

Overview of Included Articles: In this subsection, a descriptive overview of the included articles to include the Title, Country, Year, Journal, STEMM Field, and the Type of Mentorship will be discussed. It is important to note that a scoping review, by its very nature, is unable to answer questions related to "feasibility, appropriateness, meaningfulness, or effectiveness" [6], thus this section is composed of numerical data and observational commentary.

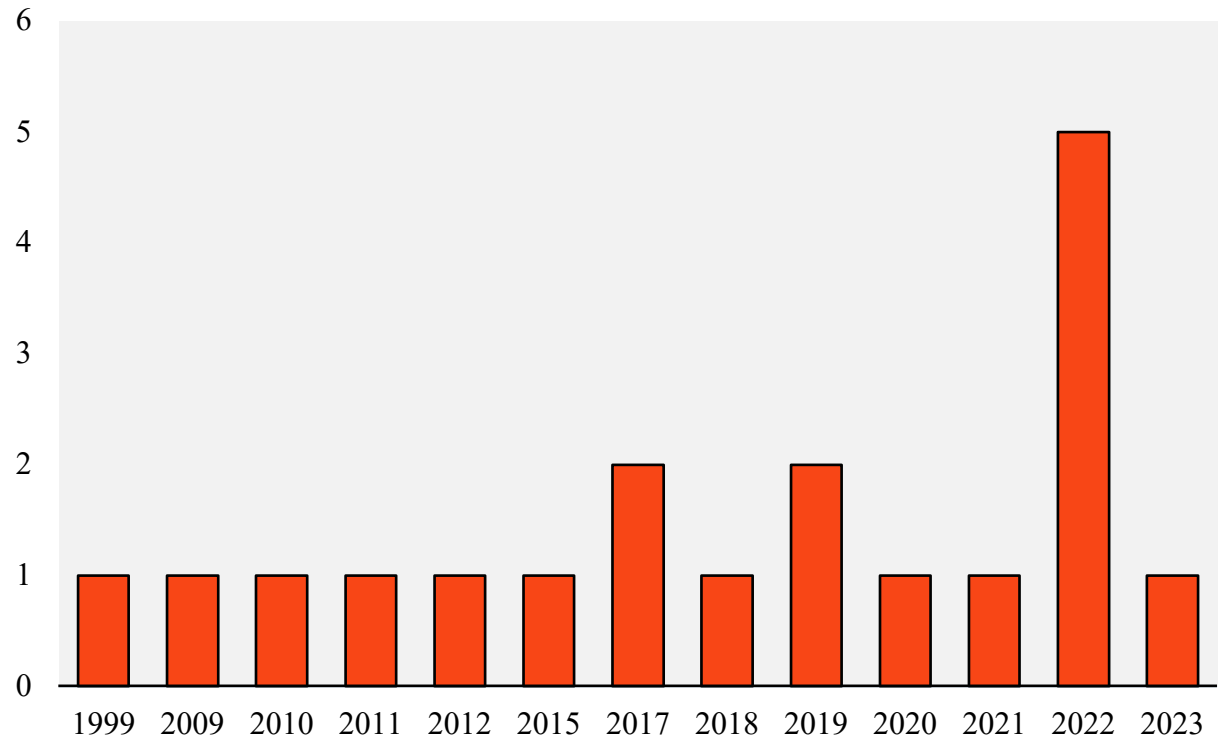

Figure 3. Number of included articles (n = 20) per year

Based on the number of articles published per year on the topic of mentorship within student organizations (Figure 3), it is evident that few such articles exist, and this area requires further study. It is interesting to note that there was an uptick in publications in 2022; the Covid-19 pandemic may have been a factor in this sharp increase.

Table 4. Number of included articles (n = 20) by journal

Rank	**Journal**	***n***
1	Academic Medicine	1
	Alberta Journal of Educational Research	1
	American Journal of Pharmaceutical Education	1
	Child and Family Social Work	1
	Children and Youth Services Review	1
	Critical Ultrasound Journal	1
	Frontiers in Public Health	1
	JMIR Medical Education	1
	Journal of Cancer Education	1

	Journal of Clinical and Translational Science	1
	Journal of Engineering Education	1
	Journal of Negro Education	1
	Journal of Prosthodontics	1
	Journal of Surgical Education	1
	Medical Science Educator	1
	Oppression and Resistance	1
	Peabody Journal of Education	1
	PLoS ONE	1
	Reference Services Review	1
	Scholarship and Practice of Undergraduate Research	1

As shown in Table 4 above, each article included was published in a different journal. This finding suggests that there is not one place for such studies at this time.

Table 5. Number of included articles (n = 20) by country

Rank	**Country**	***n***
1	United States of America (USA)	18
2	Islamic Republic of Pakistan (Pakistan)	1
	Republic of Türkiye (Turkey)	1

As shown in Table 5 above, 18 of the 20 articles selected for inclusion originated from the United States of America. Since only English-language articles were included in this review, it makes sense that many originated from America.

Table 6. Primary STEMM field for included articles (n = 20)

STEMM Field	***n***	**%**
Science	8	40
Technology	1	5
Engineering	2	10
Mathematics	0	0
Medicine	9	45
Total	20	100

As shown in Figure 6 on the previous page, there were many articles pertaining to medicine and science, which is perhaps unsurprising given the strong emphasis on mentorship in those fields. It is interesting that there were no included articles that describe mentorship in mathematics student organizations. Additionally, the low number of engineering representation here suggests a need for more research in this area.

Table 7. Primary type of mentorship discussed across the included articles (n = 20)

Type of Mentorship	***n***
Traditional	9
Effective	8
Critical	3
Total	20

As shown in Figure 7 above, the categorization by mentorship type was based on the mentorship indicators discussed earlier in this section. In most cases, the text would state that mentorship was occurring within a given student organization and provide an illustrative example; categorization therefore was based on assessment of the example given as it fit into the test model.

4.2 Mentorship Framework Development

There are multiple forms of mentorship described in the literature [1], but they can broadly be categorized into either traditional mentorship, effective mentorship, or critical mentorship. The test model examined here will be refined over time and published later with revisions. In this conceptualization, traditional mentorship refers to situations wherein mentorship is viewed as a one-way exchange of advice, support, and guidance from the mentor to the mentee. Effective mentorship reconceptualizes the mentor-mentee relationship as a two-way interactional model wherein the mentor also stands to benefit from the relationship. Critical mentorship is effective mentorship with additional components related to autonomy, empowerment, and affinity, which provide an add-value to one or both parties in the mentoring relationship.

Mentorship in higher education most often adheres to traditional mentoring frameworks, which are primarily concerned with mentor-driven mentee development and can be grouped into two factions [22]: development through assimilation into institutional culture (this may occur by increasing mentee involvement [23], [24], [25], facilitating mentee integration [26], [27], [28], and providing the mentee with support and challenge [29], [30]) and development through emulating the mentor (which occurs by the mentor serving as a role model [31], [32], [33]). Traditional mentoring frameworks assume that student mentees can only ever be impacted in positive ways by institutions of higher education [22].

The literature on traditional mentorship has described improvement in the mentoring model through the concept of effective mentorship [34], [35]. This concept was conceived within the context of university research, with faculty members mentoring the students working in their laboratories. The literature suggests that anyone “self-motivated to enroll” in skills training on the

following six mentoring competencies can become an effective mentor [34]: "1) Maintaining effective communication, 2) Establishing and aligning expectations, 3) Assessing mentees' understanding of scientific research, 4) Addressing diversity within mentoring relationships, 5) Fostering mentees' independence, and 6) Promoting mentees' professional career development."

Critical mentoring emerged from the idea that institutions of higher education are historically and structurally rooted in inequality [2], and that encouraging students from historically marginalized communities (HMC) to assimilate into these spaces emphasizes their "otherness" and sends the message that "you don't belong here, so we are going to fix you so you can belong" [2]. Critical mentorship was designed to counteract these messages by providing the mentee with a mentor-activist, someone who will advocate in the mentee's best interest, but also empower them to pursue their own goals [22]. Critical mentors are described as those who empower mentees to critically engage with and challenge inequitable institutional systems, and work together with the mentee towards institutional change [2]. The information discussed in this sub-section is summarized in Table 8, below.

Table 8. Overarching concepts identified in the literature organized by mentorship type

Mentorship Types	**Overarching Concepts**
Traditional	Increasing involvement
	Facilitating integration
	Providing support and challenge
	Role modeling
Effective	Maintaining effective communication
	Establishing and aligning expectations
	Assessing mentees' understanding of scientific research
	Addressing diversity within mentoring relationships
	Fostering mentees' independence
	Promoting mentees' professional career development
Critical	Provoking critical engagement with institutional culture
	Empowering mentees to achieve their goals

In the earliest days of test model conceptualization, the distinction between traditional mentorship and effective mentorship was unclear, so it was reflected upon, questioned, and discussed until it became evident that traditional mentorship had a fixed mindset perspective whereas effective mentorship emphasized a growth mindset. This determination made it clear that traditional mentorship and effective mentorship were separate mentorship types. The three-type test model was utilized as the starting point for thematic codebook development.

Codebook Development, Testing, and Refinement: The first iteration of the codebook (version 1) had mentorship types, concepts, and themes from the literature, however, more work was needed before the codebook could be utilized for coding purposes owing to a lack of strong definitions [12]. In the context of RTA, *strong definitions* refers to the clear and concise articulation of a theme that captures its core essence, scope, and boundaries, and should include illustrative examples and contextual reference for the theme [12]. Several iterations (versions 1 – 4) were constructed by the researcher going between literature and the codebook to create strong definitions for each theme. This is summarized in Figure 4, below:

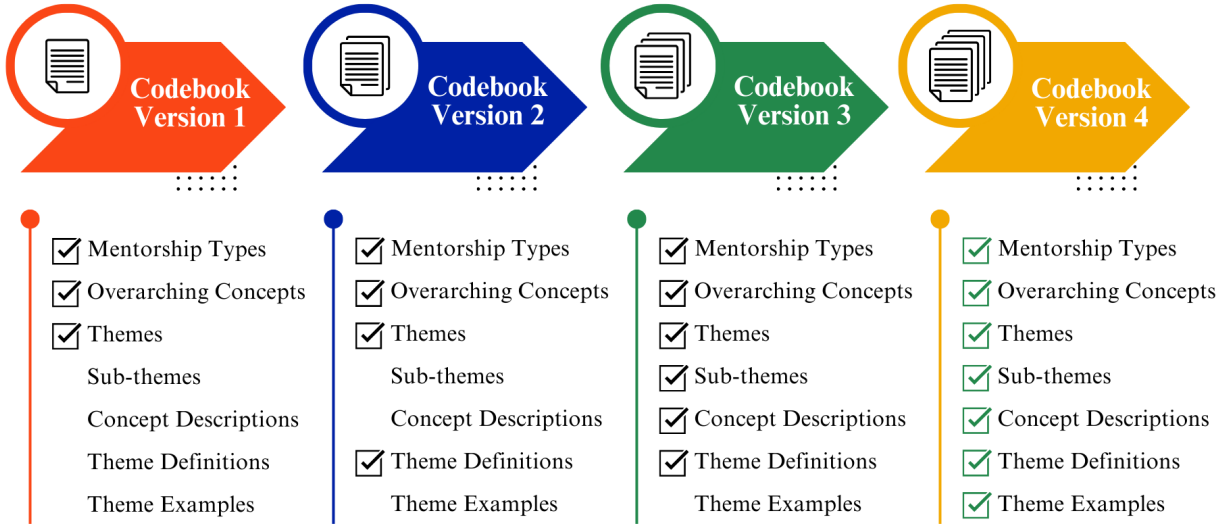

Figure 4. Visual summary of codebook development

The process of codebook development included weekly meetings with the research team to discuss thoughts and ideas, which strengthened the quality of the descriptions, definitions, and examples included in the codebook. Between versions 2 and 3 (first pass) and then again between versions 3 and 4 (second pass), the codebook was tested against field notes from a yet to be published study on the same topic. When the results of the first and second pass were compared, the research team found that a much better job of capturing the desired themes was done in the second pass.

At this point in time, it became evident that more themes might need to be added to the codebook in order to fully capture the sentiments expressed in the test data set beyond what is currently included. The latest iteration of the codebook as of the time of writing (version 4) has been provided in Appendix A (after the references) on an as-is basis.

Illustrative Example of Development for One Theme: For the purposes of this discussion, one theme was picked at random, and snapshots of this theme were taken throughout codebook development to demonstrate the changes that have taken place over the course of this process. This example is shown in Figure 5, on the following page. Subthemes are not shown for this theme, as none have been developed for it. Additionally, some columns of the codebook are not visible in this view to allow for better legibility of the figure.

Version 1

Mentorship Types	Mentorship Framework	Overarching Concepts	Themes
	Where the [overarching concept] originated from in the literature.	*[Theme] fits into [concept].*	*When [code] is mentioned, [theme] is being discussed.*
Traditional	Tinto's theory of academic and social integration [26], [27], [28]	Facilitate integration	Familiarity and commitment

Version 2

Mentorship Types	Concepts	Themes	Definitions
	[Theme] fits into [concept].	*When [code] is mentioned, [theme] is being discussed.*	*[Codes] are interesting things participants said. As used here, [code] means [definition].*
Traditional	Facilitate integration	Familiarity and commitment	Feeling more comfortable at and loyal to the institution

Version 3

Mentorship Types	Concepts	Concept Descriptions	Themes	Definitions
	[Theme] fits into [concept].	*Brief explanation of the [overarching concept].*	*When [code] is mentioned, [theme] is being discussed.*	*[Codes] are interesting things participants said. As used here, [code] means [definition].*
Traditional	Facilitate integration	Mentors help mentees assimilate into the institution by exposing them to positive academic experiences and promoting positive relationships with peers	Familiarity and commitment	Feeling more comfortable at and loyal to the institution

Version 4

Mentor Types	Concepts	Concept Descriptions	Themes	Definitions	Examples
	[Theme] fits into [concept].	*Brief explanation of the [overarching concept].*	*When [code] is mentioned, [theme] is being discussed.*	*[Codes] are interesting things participants said. As used here, [code] means [definition].*	*Examples of what [codes] may look like.*
Traditional	Facilitate integration	Mentors help mentees assimilate into the institution by exposing them to positive academic experiences and promoting positive relationships with peers	Familiarity and commitment	Feeling more comfortable at and loyal to the institution	Mentor invites mentee to a departmental networking event

Figure 5. Changes to the *Facilitating Integration* theme from version 1 to 4 of the codebook

4.3 Study Limitations

Scoping Review Search Strategy: Though intentionally broad, the search string used for the scoping review resulted in a large number of irrelevant articles. For example, there were many articles about professional sports clubs being imported for the initial screening. There currently is no way to exclude them without excluding, for example, sports related student organizations, therefore this limitation is likely to carry over into later work on this topic. The search strategy used also included many examples of mentorship outside of higher education; the researcher recognizes that not all articles will explicitly state in their abstract or title whether or not the mentorship example occurred in the context of higher education and that post-secondary students may serve as mentors to community members or receive mentorship from industry professionals, for example. For these reasons, "higher education" was not used as part of the search string.

5. Conclusions and Implications for Future Work

This paper covers the development of a thematic codebook which will be applied to interview and survey data in future work on the role critical mentorship plays in the professional formation of STEMM students. While literature is scarce on this topic, there is enough agreement within literature to create a codebook which could be applied in this way.

1) What is the current landscape of the research literature on STEMM mentorship that occurs within student organizations at institutions of higher education? The results of the scoping review conducted as part of this study revealed that few articles have been published regarding STEMM mentorship which occurs in the context of student organizations. The majority of articles that have been published in this area discuss traditional mentorship.

2) Does the mentorship described in these articles exemplify critical mentorship as defined in the literature? Only three of the articles identified in the scoping review [37], [42], [49] were classified as having aspects of critical mentorship. Each of the three articles tackle issues related to race and ethnicity, with the third article also touching on socioeconomic status.

3) Does the addition of critical mentorship components have a synergistic effect for STEMM students who serve as mentors or mentees through their student organizations? While the codebook developed in this study was sufficient for the analysis of scoping review data, the lack of research articles on critical mentorship within student organizations did not allow for the development of themes related to synergistic effects within this context. These themes are expected to emerge from the research currently being conducted on mentorship in this and other institutional settings, allowing the revised codebook to be utilized in future studies on mentorship.

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7. References

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Appendix A: Codebook

Mentor Types	Concepts	Concept Descriptions	Themes	Definitions	Examples
	[Theme] fits into [concept].	*Brief explanation of the [overarching concept].*	*When [code] is mentioned, [theme] is being discussed.*	*[Codes] are interesting things participants said. As used here, [code] means [definition].*	*Examples of what [codes] may look like.*
Traditional	Increase involvement	Mentors encourage mentees to actively engage in academic, extracurricular, and/or research activities to encourage success / degree completion	Student participation in activities	Academic: attending study groups, asking for homework help, going to remediation sessions, studying at the library, etc.	Mentor submits mentee's name for an award, or encourages them to present at a conference
				Extracurricular: joining student orgs / Greek life, attending school spirit / sporting events, etc.	
				Research: pursuing research experiences, doing literature reviews, conducting experiments, working on research studies, etc.	
	Facilitate integration	Mentors help mentees assimilate into the institution by exposing them to positive academic experiences and promoting positive relationships with peers	Sense of belonging, informal social interactions, familiarity and commitment	Sense of belonging: feeling that you fit in at / with the people at your institution and they care about you (*they do not need to be friends*)	Mentor invites mentee to a departmental networking event
				Informal social interactions: meeting new people to form positive relationships with; hanging out with people outside of classes	
				Familiarity and commitment: feeling more comfortable at / loyal to your institution	
	Provide support and challenge	Mentee growth / development occurs through overcoming academic and social challenges with the support of their mentor	Regular meetings to address concerns	Members of the mentor/mentee relationship have recurring meetings at predetermined and regular intervals for the purpose of discussing mentee progress	Mentor gives mentee tips on dealing with a tough professor, making friends, etc.
	Serve as role models	Mentors are more experienced and model how mentees should think and reason; since mentees look up to their mentors, they try to become more like them both intellectually and morally; as mentee advances, they may need a new mentor	Mentor is more advanced than mentee, mentor provides mentee guidance based on their experience, mentor's attitudes and behaviors should be emulated	Mentor is more advanced than mentee: Mentor is older than their mentee / has more experience than their mentee	Mentor is a research professor, so mentee wants to become a research professor as well. Mentor models ethical behavior and research practices which the mentee emulates
				Mentor provides mentee guidance based on their experience: Since the mentor is more advanced, they can share how they handled similar situations in the past	
				Mentor's attitudes and behaviors should be emulated: Mentor leads by example, showing the mentee how they should be / act. Mentee looks up to and wants to be more like their mentor, so they follow in their footsteps.	
Effective	Align expectations	Mentors and mentees have conversations where they set expectations for the relationship and adhere to those expectations	Mentor and mentee are explicit about expectations	Mentor and mentee are explicit about expectations: there are rules or guidelines for the mentoring relationship so that everyone knows what to expect from each other; these should be agreed upon by all parties prior to starting the mentoring relationship.	Mentor can refer to their mentorship agreement to hold the mentee accountable and vice versa

	Assess understanding	Mentors are able to recognize when a mentee does not understand something and can remediate that	Detect and assess knowledge gaps	Detect and access knowledge gaps: Mentor should be able to tell when the mentee needs help with something and remediates that	Mentor notices that mentee is struggling with a certain research technique and shows them how to do it properly
	Communicate effectively	Mentors demonstrate active listening skills and are sensitive to their mentee's communication needs	Proactive / intentional communication	Proactive/intentional communication: Mentor anticipates issues the mentee might encounter and tries to prevent these potential issues from happening by communicating with the mentee ahead of time (proactive). Mentor has structures in place – agendas, captioning, etc. – to ensure that meetings are effective and mentee's communication needs are met (intentional).	If meeting over Zoom, mentors should allow mentees to record meetings / use live transcription and sets up a way to share and store information securely
	Address equity and inclusion	Mentors should be aware of cultural differences and similarities between themselves and their mentees and work to counter their unconscious biases	Cultural awareness, inclusive environment	Cultural awareness: Mentors are aware of the differences / similarities between themselves and their mentees by virtue of their backgrounds / lived experiences Inclusive environment: Mentors use their understanding of cultural differences towards countering their unconscious bias (so they can avoid "othering" their mentee)	Mentors should avoid microaggressions, not be racist, not promote stereotyping
	Foster independence	Mentor treats mentee as an equal and encourages them to trust themselves/make their own decisions	Mentees have autonomy in decision-making	Mentees have autonomy in decision-making: Mentors encourage mentees to make their own decisions / pursue their interests rather than just doing whatever the mentor wants	Mentor lets mentee know that they can pursue their interests
	Promote professional development	Mentors recommend/provide skills-building and confidence-building opportunities for mentees	Discussion of career goals, sharing resources	Discussion of career goals: Conversations center mentee's future careers; mentors might recommend certain courses to help mentees gain an advantage or develop specialized knowledge / skills aligned to their career goals Sharing resources: "Resources" is defined very broadly to include knowledge (personal or directing mentees towards a knowledge source), contacts (personally connecting their mentee with people who can help them),	Mentor forwarding emails about professional development opportunities to mentee. Mentor introducing mentee to an industry partner.
Critical	Provoke critical engagement with institutional culture	Mentors encourage mentees to resist assimilation and provoke institutional change through a "be the change you want to see in the world" approach (i.e. lead by example) *To contrast with effective mentorship: mentors should be anti-racist (active) instead of just not being overtly racist (passive)*	Consider intersectionalities and intersecting identities, recognize how perception affects people differently, dialectical relationship between	Consider intersectionalities and intersecting identities: Both intersectionality and intersecting identities have to do with social categories. Intersectionality is the interconnected nature of social categories such as race, ethnicity, socioeconomic class, gender identity, sexual identity, and disability as they apply to a given individual or group, regarded as creating overlapping and interdependent systems of discrimination or disadvantage. (E.g. being a person of color puts you at a disadvantage, but being a disabled person of color	Mentor requires mentees to take regular breaks because they feel it is important for their well-being, despite this not being part of the institutional culture. Mentor corrects someone who mispronounced their

			mentee and institution	puts you at a greater disadvantage). Intersecting identities refers to how an individual's identity consists of multiple, intersecting factors, which make them unique and affect how they move through the world. (E.g. A white gay man has more privilege than a white lesbian, but both are still white and therefore hold privilege over non-white gay people. Similarly, a white femme lesbian has privilege over a white butch lesbian.)	mentee's name or misgendered their mentee. *Mentors should be anti-racist (active) instead of just not being overtly racist (passive)*
				Recognize how perception affects people differently: Mentors should go beyond consideration and take the time to critically assess the dynamics of privilege present in the mentoring relationship so that they can leverage their privilege to help their mentee (e.g. there may be times where mentors need to protect their mentees from others).	
				Dialectical relationship between mentee and institution: Mentees and their institution are in a direct relationship to each other such that the institution is defined by the people in it (the vast majority of people making up an institution of higher learning are students – the mentees, in our case), but the people are shaped / molded by being a part of the institution. As part of the institution, the mentee can either maintain the status quo or work to change it – mentors should encourage mentees to work towards creating a positive institutional cultural, even though this breaks from institutional norms.	
	Empower mentees to achieve their goals	Mentors and mentees are equals who build community with and learn from each other; this process is often marked by friendship	Mentor and mentee have a reciprocal relationship, mentor and mentee are co-learners, mentoring results in friendship	Mentor and mentee have a reciprocal relationship: The mentoring relationship is viewed as a value-add for both the mentor and the mentee.	Mentor and mentee work together to start a community initiative
				Mentor and mentee are co-learners: Both mentor and mentee learn from each other over the course of the mentoring relationship.	
				Mentoring results in friendship: Mentors and mentees become friends as a result of mentorship. This is common in peer mentorship but can happen in other kinds of mentorship once the power differential is removed (a professor who serves as a mentor might befriend the mentee after graduation).	