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Supporting Undergraduate STEMM Education: Perspectives from Faculty Mentors and Learning Assistants in Calculus II

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Abstract: In higher education, Learning Assistants (LAs)—a relatively recent evolution grounded in peer mentorship models—are gaining popularity in classrooms as universities strive to meet the needs of undergraduate learners. Unlike Teaching Assistants, LAs are undergraduate students who receive continuous training from *faculty mentors* in content-area coaching and pedagogical skills. As near-peers, they assist assigned groups of undergraduates (students) during class. Research on LAs suggests that they are significant in mitigating high Drop-Fail-Withdrawal rates of large enrollment undergraduate science, technology, engineering, mathematics, and medical (STEMM) courses. However, there is a dearth of description regarding the learning between LAs and STEMM faculty mentors. This paper reports on perspectives of faculty mentors and their cooperating LAs in regard to their learning relationships during a Calculus II at a research-oriented university during Spring of 2020. Using an exploratory-descriptive qualitative design, faculty (oral responses) and LAs (written responses) reflected on their relationship. Content analysis (coding) resulted in four salient categories (by faculty and LA percentages, respectively) in: Showing Care and Fostering Relationships (47%, 23%); Honing Pedagogical Skills (27%, 36%); Being Prepared for Class and Students (23%, 28%); and Developing Content Knowledge in Calculus (3%, 13%). Benefits of LAs to faculty and ways to commence LA programs at institutions are also discussed.

Keywords: exploratory-descriptive qualitative (EDQ) design; faculty perspectives; learning assistant; undergraduate STEMM education

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1. Introduction

There has been a shift in higher education to identify and implement improved supports for faculty teaching introductory-level, large enrollment courses for undergraduates, especially within the science, technology, engineering, mathematics and medical (STEMM) disciplines [1]. The initial credit-bearing college-level courses for degrees in STEMM are colloquially known as 'gateway' courses. Unfortunately, these foundational classes often bar students from progressing into future STEMM coursework or completing their STEMM degrees [2–4]. These gateway or barrier STEMM courses have had historically and persistently high Drop-Fail-Withdrawal (DFW) rates [5], which often dissuade undergraduates from continuing in their STEM majors or collegiate studies [6]. One such STEMM-based gateway course is calculus, in which up to one fourth of undergraduates fail and are unable to matriculate into further STEMM coursework, often leading them to longer degree completion [7] or causing to change majors and forgo their pursuit of a STEMM future [8,9].

Therefore, educators in tertiary education are seeking means to mitigate STEMM student attrition by improving undergraduates' learning experiences in these foundational STEMM courses [10,11].

Research suggests that in-class experiences (e.g., active versus passive learning, lecture-driven versus activity-driven) and supports (greater interaction with more capable peers) can greatly influence students' affective and learning experiences in STEMM [12–14], especially in Calculus [10,15], and among historically under-represented groups (e.g., first generation, racial, ethnic and gender minorities) in STEMM [16–19].

One common strategy among institutions of higher education to support undergraduate education in STEMM has been employing Teaching Assistants (TAs). In the United States, TAs are responsible for as much as 91% of undergraduate instruction in STEM courses [20], especially among the introductory (gateway) courses [21,22]. Typically, TAs are discipline-specific graduate students that assist faculty in STEMM courses by preparing answer keys or supplemental course materials, taking attendance, proctoring examinations, grading student assignments and tests, recordkeeping (e.g., taking attendance, posting scores), holding office hours, and/or assuming teaching responsibilities in laboratory or recitation sections [23–27]. Notably, few of the TAs' duties take place during class when the faculty member is providing instruction directly to students. This note is important as studies indicate that TAs are most effective when they directly interact with students, either as content experts for tutoring or providing real-time affective encouragement [28]. Hazari et al. ([29], p. 27) similarly found that the greater interaction between TAs and students *in class*, led to more positive outcomes for students. They concluded that, "given sufficient knowledge of the material, TAs must be encouraged to be proactive in interacting with their students, and to pay attention to affective issues; friendliness, appropriate use of encouragement and language, exhibitions of interest or enthusiasm." These aforementioned studies suggest that greater interaction between more capable peers and students is warranted. Rather than the 'behind the scenes' work of traditional TAs, there are needs in providing the content reinforcement and affective supports to best encourage and sustain undergraduate student learning in STEMM.

One such iteration of the TA model, which intends to address the needs for enhanced interaction between students and in-class, is the Learning Assistant (LA) program [30]. Originating out of the University of Colorado Boulder [31], LAs are 'near peers,' meaning, undergraduate students who recently completed a STEMM course successfully (evidenced by high grades or mastery of the course material) with an interest in growing their STEMM content knowledge and pedagogical skills. As such, they are mentored weekly on STEMM content by the professor of the course (content faculty mentor) and a second professor that coaches them on best practices in student-based, in-class supports (pedagogical faculty mentor). Herein, STEMM faculty members who work with LAs are referred to collectively as simply *faculty mentors*. Throughout the semester, LAs meet weekly with their faculty mentors and write weekly journal entries to discuss and reflect upon their experiences supporting their undergraduate STEMM students (therein simply 'students'). Research on LAs indicates that they are effective in reducing DFW rates [32,33], enhancing student interaction and generative conversations in class [34], as well as improving both student satisfaction and achievement [35–37] in STEMM courses.

Further, it may be unsurprising that research has found additional positive outcomes for LAs as STEMM students beyond the obvious benefits for the peers they serve. Studies by Nadelson and Finnegan [38] as well as Close et al. [39] found through independent studies that undergraduates who had served as an LA held more generative perspectives on the purpose of learning (focusing on mastery of concepts than recitation of facts) and developed a strong professional identity in STEM as well as in their content area (of Physics), respectively. Some institutions are leveraging the LA program to prepare future STEMM teachers [40–44]. An important contributing element to these outcomes is the relationships between LAs and their faculty mentors. McHenry et al. ([45], p. 258) found in their preliminary study of LAs and faculty mentors that there was "a broadening of both the faculty and LA conceptions about teaching and learning," suggesting a reciprocal nature of learning occurring between these two groups. Sabella et al. [46] in a self-study of the LA program at Chicago State University explored the nature of relationships between LAs and content faculty mentors, finding that faculty who were most willing to relinquish some degree of control over the classroom had the most collaborative partnerships with their LAs. They cautioned that the release of responsibility onto the LA for pedagogical decisions is difficult, yet necessary, for faculty to best utilize LAs in undergraduate STEMM courses. Conceptually, this trust is important between LAs and faculty because it is through close-knit and regular coaching, coupled with avenues to exercise agency, in which LAs gain ownership over their work with students. This ownership is a vital first step in having students gain not only autonomy, but also empowerment [47,48]. Thus, LAs are able to garner additional knowledge and skills through expanded avenues of access (in-class, with students) that enhance their ability to function [49] and remain committed to that work [50].

This research sought to extend the work of Sabella et al. by taking a deeper look into the learning that occurs from the relationships between faculty mentors and LAs. To that end, we qualified the types of learning (i.e., content and pedagogical strategies in teaching undergraduate STEMM students) that occurred between these groups by exploring mentor faculty's and LAs' perceptions of their professional relationship (i.e., educating STEMM undergraduate students). Through a faculty mentor focus group and data from LAs' written reflections and open-ended questionnaire, we sought to categorize the learning that occurred between two STEMM faculty members and their 10 LAs supported Calculus II course at Texas Tech University in Spring of 2020, which began with face-to-face interactions and abruptly transitioned to an all-virtual format. By gathering data on the perspectives of faculty and LAs independently, we are able to categorize and juxtapose their perceived outcomes of the learning gained through their professional relationship, and evidenced by serving STEMM undergraduate students in the classroom. Findings of this research provide a greater visualization of the research-based affordances of the LA program to both STEMM students and LAs working with faculty mentors. Further, this research provides insight to best practices in most effectively relating to LAs for STEMM faculty members who are working in or considering LA programs at their institution.

2. Materials and Methods

To describe the nature of the learning between faculty mentors and their LAs, an exploratory-descriptive qualitative (EDQ) design was used to collect and analyze data [51]. EDQ is particularly useful to both explore and describe dual perspectives, like between nurse and patient, or in this case, STEMM faculty mentors and LAs. Since the work is exploratory and descriptive, a content analysis approach was selected as it is able to: (1) explore the commonalities within the data [52] and (2) provide "a descriptive approach in both coding of the data and its interpretation of quantitative counts of the codes" ([53], p. 400). Further, content analysis is a useful approach to analyze text-based data [54] to explore salient meanings (categories) and their frequency [55]. By engaging in a content analysis, textual information highlights relationships through the perspectives and thoughts within each group of participants of study [56]. Due to the exploratory and qualitative nature of the study, an inductive approach was selected to code the data [57].

Text data were comprised of responses from two groups: two STEMM faculty mentors (focus group) and 10 of their cooperating LAs (written reflections and an open-ended questionnaire). This group represents a portion of the LA program at Texas Tech University that serves STEMM undergraduate students for Calculus II and Chemistry II. These three qualitative sources of data were appropriate for a content analysis [58] and provided insight to the learning that occurred between these groups from each perspective. This study is a part of a larger set of studies about LAs [59], therefore, Institutional Review Board approval was sought and gained for the protection of research participants prior to data collection for analysis and interpretation.

STEMM faculty mentor data were sourced from a transcript of a 40 min online focus group (using video conference software) with STEMM faculty members, reflecting together on their experiences coaching and mentoring the Calculus II LAs in the Spring and Summer of 2020. Recall that the LA system consists of one faculty member serving as the content mentor and the other faculty member as a pedagogical mentor. Both faculty mentors were prompted during the focus group to discuss the types of coaching and mentoring they provided to LAs in Spring of 2020; they also co-constructed understandings of what they had learned, from LAs, during the process. One faculty member is a professor of mathematics with 20 years of experience at the University. He also serves as the department coordinator for Calculus II. The other faculty member teaches courses in cell biology, genetics, and human physiology; he serves as the director of a faculty development program for best practices in teaching STEM and the LA program within the university center for teaching and learning.

Text data from LAs were sourced from weekly written reflections that they had made as a part of their LA program and their responses to an online open-ended questionnaire after the course concluded in Summer of 2020. Ten LAs (out of 13 total LAs) participated in the study by both recording weekly reflections (emailed to mentor faculty and researchers) during the Spring term and responding to the open-ended questionnaire in the Summer term. The sampled LAs were all undergraduate students who had recently taken Calculus II, evidenced mastery of the material (achieving a grade of As and Bs in previous Calculus courses), and expressed interest in serving as an LA. Notably, LA applicants were screened for their responses to multiple open-ended questions. These questions were critical in determining the applicants' abilities to communicate effectively [60]. Each participant was given a number for data curation purposes and to provide the reader evidence many different responses contributed to the data analysis. Among the four female LA participants, two identified as white (participants 1 and 2) and two as Latinas (participants 3 and 4). Among the six men, three identified as white (participants 5, 6, and 7), one as Latino (participant 8), one as African (participant 9), and one as Southeast Asian (participant 10).

Data (in transcript form) were read thrice to explore the texts' descriptions of experiences of learning vis à vis from faculty mentors and/or LA relationships. From the first pass through the data (i.e., the *preparation step* of content analysis), 83 relevant pieces of data (i.e., statements from STEMM faculty mentors and writing from the LAs) were pulled into an excel sheet for researchers' analyses, parsed by the faculty mentors' (n = 30) and LAs' (n = 53) responses. In the second pass (i.e., the *organizing step* of content analysis), four salient *categories* emerged. Per the content analysis method, categories express the descriptive or manifest content found within text [61], "based on the frequency of its occurrence in the text. This approach is objective, systematic, and concerned with the surface meaning of the document" ([53], p. 403). In the third pass, data were coded (by a single researcher) and then intercoded (by a second researcher). Frequencies of statements, per each category, were summed (frequency count) and averaged (for percentages). Data tables were produced to highlight the relationships that emerged from the data and to address the research purpose (see Tables 1–4 in Section 3, the results).

Table 1. STEMM faculty mentors coding: category, frequency, percentage of total and example responses (n = 30).

Salient Category	Frequency	Percent	Representative Statement(s)
Showing Care and Fostering Relationships	14	47%	"And so it's really about them [LAs] sharing being able to share their experiences with how they struggled and overcame barriers to the learning when they were taking the class." (1:17)
Honing Pedagogical Skills	8	27%	"We spent a lot of time talking about how you recognize a student that needs help, what sort of questions you asked to get them to tell you that they need help [such] to force them to, I guess, admit that they're stuck kind of thing. And so that was mostly what our weekly trainings were on the pedagogy side, both pre [before] and post [after class]." (10:45)
Being Prepared for Class, Students	7	23%	"So we met as a group and I would go through the PowerPoint [lecture of what] we're going to do that week; to sort of explain where the pitfalls were what to be careful about what to emphasize. [We] make sure they know how to do this [content] because this is going to kind of thing is going to be on the test." (7:45)
Developing Content Knowledge	1	3%	"So the LAs always had those [content] videos to watch ahead of time to sort of make sure they knew how to do the [Calculus] problems. But even then, they still had lots of questions." (8:02)

Table 2. LA coding: category, frequency, percentage of total and example responses from questionnaire data (n = 16).

Salient Category	Frequency	Percent	Representative Response(s)
Honing Pedagogical Skills	7	44%	"We take note and adapt to the students taking the class and make many decisions on the fly as opposed to just simply giving them [students] the materials and answers." (participant 8)
Showing Care and Fostering Relationships	4	25%	"The faculty genuinely care about the students here, which is something I never expected to happen. In a large classroom, the LAs are often compared to TAs in the sense that they speak to the students instead of the professor. But, this is not at all what's been happening with this course, and I love that so much." (participant 1)
Being Prepared for Class, Students	3	19%	"It is important to be prepared. Discussing with [faculty mentors] beforehand [has] really helped me out." (participant 10)
Developing Content Knowledge	2	12%	"My knowledge on the content is limited. This is especially the case compared to my professor, but more importantly, each of the learning assistants seem to have their own perspectives as well. This is probably because we all mostly learned calculus in different places. Through this, my knowledge of the content has certainly become more diverse." (participant 7)

Table 3. LA coding: category, frequency, percentage of total and example responses from journal data (*n* = 37).

Salient Category	Frequency	Percent	Representative Passage(s)
Honing Pedagogical Skills	12	32%	"The quality of mentorship during this transition I believe has increased because I was able to witness how professors handled the stress of transitioning while maintaining calmness." (participant 5)
Being Prepared for Class, Students	12	32%	"I encourage active learning through the online modality by using verbal prompting and referring to examples that [faculty mentors] covered in [LA meeting and class] to answer their [students'] questions." (participant 3)
Showing Care and Fostering Relationships	8	22%	"I am a fan of [Content Faculty Mentor]'s stories, and I love that he is trying to build a persona for the students to be comfortable with." (participant 9)
Developing Content Knowledge	5	14%	"[Being an LA] has helped me grow in my mathematics abilities." (participant 6)

Table 4. Summary table of STEMM faculty and LA coding by salient categories (*N* = 83).

Study Participants	Honing Pedagogical Skills	Showing Care and Fostering Relationships	Being Prepared for Class, Students	Developing Content Knowledge
Two Faculty Members (*n* = 30)	8 (27%)	14 (47%)	7 (23%)	1 (3%)
Ten Learning Assistants (*n* = 53)	19 (36%)	12 (23%)	15 (28%)	7 (13%)
Total (*N* = 83)	27 (33%)	26 (31%)	22 (27%)	8 (9%)

Hunter et al. ([51], p. 7) have argued that the "criticality and integrity of EDQ can be enhanced by reflecting on researcher bias, respondent validation, and peer review," which can be translated as elements of credibility, dependability, and confirmability of trustworthiness, respectively [62]. To meet the mandate of trustworthiness, the credibility of the EDQ design was met by collecting and analyzing the data per the three recommendations by Milne and Oberle ([63], p. 415) in "that (1) participants had the freedom to speak, (2) participants' voices were heard, and (3) participants' perceptions were accurately represented." Each data type (i.e., focus group data and written reflections) both recorded and related participants' voices and thoughts; hence, the group (rather than any one individual) was adequately represented in the analysis. In regard to dependability, a second researcher independently coded 67% of faculty mentor (*n* = 20) data and 75% of LA data (*n* = 40); as "it is widely acknowledged that intercoder reliability is a critical component of content analysis" ([64], p. 589). The intercoder analysis yielded a percent agreement of 85% and 83%, respectively, exceeding the 80% threshold for dependability values [65]. The intercoder's disagreements were reviewed by the primary researcher, in which his feedback was incorporated into the final coding and codes. In regard to confirmability, an audit trail was established to demonstrate how representative the responses (i.e., *representative responses*) were among sampled participants in Tables 1–3. Since there were only two faculty mentors interviewed, the audit trail consisted of time stamps made in their focus group. For the LAs, the audit trail consisted of use of their assigned number by data type (i.e., questionnaire in Table 2 and journal data in Table 3). Notably, both researchers who conducted the data analysis were external to (and not affiliated with) the Calculus II and LA programs, such to mitigate opportunities for bias.

3. Results

Tables 1–4 display the four salient categories between STEMM faculty mentors (Table 1), LAs (Tables 2 and 3). Each table is replete with frequency, percentage, and representative statements (Table 1), responses (Table 2), and passages (Table 3) (based upon the data types) to highlight the nature of the relationships and learning that occurred between sampled groups. Table 4 provides a juxtaposed view of all data (responses) to describe learning transfers between groups. Capital and italicized N represents the entire data set of statements (N = 83), whereas lowercase and italicized n is used to show the sub-sample size of statements by learning categories and participant groups.

3.1. STEMM Faculty Mentors' Perspectives

The largest category discussed between the two STEMM faculty mentors was supporting LAs learning to show care for and foster relationships with their STEMM students (n = 14), followed by honing pedagogical skills (n = 8), being prepared for class and students (n = 7), and developing their content knowledge (n = 1). Table 1 provides descriptive statistics (i.e., frequency counts with percentages) and representative statements from the focus group that typified each of the categorizations.

3.2. STEMM LAs' Perspectives

Tables 2 and 3 describe the perspectives shared by LAs in regard to learning with and from their STEMM faculty mentors. Data from the open-ended questionnaire (Table 2) indicated that the largest category with almost half of the responses was honing pedagogical skills (n = 7). One fourth of responses were about the importance of showing care for and fostering relationships with their STEMM students (n = 4), followed by being prepared for class and students (n = 3), and developing their content knowledge (n = 2). Table 2 provides descriptive statistics and representative responses that typified the categorization.

Data from the weekly journal entries show that honing pedagogical skills (n = 12) and being prepared for class and students (n = 12) tied as the top category in the weekly journal data (Table 3). To a lesser extent, the LAs described the importance of learning to show care for and foster relationships with their STEMM students (n = 8) and developing their own content knowledge (n = 5). Table 3 provides representative passages pulled from LAs' journal entries that typified the categorization with descriptive statistics.

3.3. Comparative Perspectives

Data from both groups are juxtaposed to display the categorizations (of learning) between STEMM faculty mentors and their LAs. Table 4 summarizes data from the previous three tables to provide a summary view of aggregated responses from both the faculty members and LAs. In total, three of the four categories had near equal representation in the total data set: honing pedagogical skills (n = 27); showing care and fostering relationships (n = 26); and being prepared for class and students (n = 22). Developing content knowledge had the least amount of representation (n = 8).

3.4. Limitations

Limitations of this study relate to the qualitative nature of the data and the choices for data analysis. With this study being a qualitative and perception-based, there is no impetus to generalize these results beyond the study context to a larger group of individuals. By taking an exploratory route, we strived to identify areas of research interest that can be addressed through larger, quantitative means. Second, by use of a categorical (rather than thematic) analysis, the descriptions are at face value (categories) rather than implying there are latent meanings or subtext (themes) [61]. Again, being an exploratory study, an open-ended coding schema [57] via content analysis [58] was the best analytical choice for the research design and questions. Therefore, it is presently unknown to what extent there are latent attributes within the data set.

4. Discussion

This study sought to explore and describe the perceptions of learning that occurred between STEMM mentor faculty's and their LAs' within a professional relationship of educating STEMM undergraduate students. The EDQ design and content analysis of data from faculty mentors (focus group) and their LAs (journal entries and open-ended questionnaire), suggests that the learning resulting from their relationship (in faculty and LA percentages) related to four salient categories: showing care and fostering relationships (47%, 23%); honing pedagogical skills (27%, 36%); being prepared for class and students (23%, 28%); and developing content knowledge in calculus (3%, 13%). This study suggests that within relationships that occur between STEMM faculty mentors and their LAs, their interactions (e.g., communication, correspondence, teaching and mentoring) were largely focused on developing relationships with students. Not only does this indicate that STEMM faculty mentors and their LAs have similar goals in their support paradigm for STEMM student success, but also indicate how they comparably assess their efficacy in the STEMM classroom. This has implications when selecting for LAs in STEMM subjects, meaning, a relationship-focused personality may be as important as advanced content knowledge. Although there was some variance between groups in category frequency (e.g., faculty mentors ranked showing care higher than pedagogical skills as compared to students); together, the frequencies of the first three categories were roughly equivalent. Notably, pedagogy and preparation together represent important elements for in-class STEMM learning. These findings track with previous research on LAs' pedagogical expertise, that they need training and experiences in prompting students' thinking through formative assessment [66]. Prior research and our findings suggest that the fact that LAs are still students themselves, which does not in-and-of-itself indicate that they understand the innerworkings of teaching and learning in higher education. A study by McHenry et al. [45] of an early LA program found that—despite being near-peers—LAs needed ongoing and on-the-job training to help their students learn STEMM content that they had already mastered. We recommend that greater opportunities be afforded to LAs to continue growing in their content knowledge, as it is situated within teaching and learning. This may explain why developing content knowledge, a positive and perhaps necessary component of learning as LA, had the fewest codes and frequency. Perhaps this is because having a high level of content knowledge (mastery) is a prerequisite skill for the LA program [30,31,67]. The faculty mentors' statements (from Table 1) suggest that LAs would benefit from greater mentoring and coaching in STEMM content knowledge, and sampled LAs had identified that being an LA was an opportunity to grow in their content knowledge in STEMM (from Tables 2 and 3). It is interesting to note that STEMM faculty mentors and LAs were in agreement that pedagogical knowledge was more important than extending one's content knowledge. This finding emphasizes that despite LAs being selected for their prior knowledge in STEMM, there is an explicit need for opportunities among LAs to train and practice their nascent pedagogical skills in the undergraduate STEMM classroom. We recommend when selecting for LAs, the potential for pedagogical learning should be considered when selecting LAs that have STEMM content knowledge. We echo recommendations from the Learning Assistant Alliance that content (alongside pedagogical) coaching ensures LAs are receiving the needed background in STEMM content to feel and be effective with their undergraduate STEMM students [68].

The most salient category was showing care for and fostering relationships with students. This sole category was representative of nearly half of the mentor faculty's data and one fourth of the LAs' data. Similarly, Top's ([69], p. iii) "research found that LAs bring class, content, and institutional knowledge into their interactions with students as well as *cultivating personal relationships with students* [emphasis added] and employing pedagogical skills in the classroom" as the three central components of her model for LA effectiveness. This indicates that LAs are moving beyond diffusing in-class conflicts [70], towards sources of genuine encouragement for STEMM students [30]. These types of discussions about supporting students, between faculty mentors and LAs, may also help to consolidate their purpose (in teaching) and forge their own relationships, affirming their values (to learning). Schick ([30], p. 24) concluded from her research on LAs at Montgomery College that "LAs form positive relationships with their faculty mentors, helping them to grow and mature along their academic paths. STEM classes are [thusly] transformed into more student-centered active learning and collaborative environments, increasing the potential for student success." Hence, this research study contributes to the literature by emphasizing the prominent importance of cultivating relationships not only between faculty mentors and LAs, but also with undergraduate students *themselves*. In particular, this adds to the literature on peer-to-peer mentoring because these findings reinforce the importance of nurturing non-cognitive needs of students, from their LAs, in undergraduate STEMM support programs.

Prior research and the findings from this study suggest that the field may be viewing the mentor faculty-LA relationship in reverse. Rather than focusing on student success and moving backwards in developing LAs, we must first build foundational relationships between STEMM faculty mentors and LAs so LAs can feel supported and empowered in meeting the common goal of creating student-centered, active-learning environments with their STEMM faculty in undergraduate STEMM courses. Additionally, we should recruit LAs that not only have content knowledge, but also the potential for building pedagogical skills and valuing the importance of forging relationships with students. Sabella et al. [46] found that when faculty mentors actively collaborated with their LAs, those relationships yielded the best results for the parties involved as well as their STEMM students. We would suggest that relationship and community building is an important and mirrored—even perhaps reciprocal—type of learning that occurs between STEMM faculty mentors and their LAs. Further research is warranted to more deeply explore how categories of learning influence LA agency, learning, motivation, and persistence in the LA program, as well as moderating student learning outcomes in STEMM. For example, a longitudinal study on students' STEMM learning outcomes when recruiting LAs through different selection factors (e.g., those with relationship-focused dispositions and a potential for garnering pedagogical expertise) than only content proficiency. Such a study would broaden participation of students in LA programs and strengthen claims that relational mindedness is a vital disposition among STEMM faculty mentors and LAs when effectively serving undergraduate STEMM students.

5. Conclusions

This study sought to explore the perceptions of learning that occurred between LAs and their STEMM faculty mentors from their professional working relationship and situated to a university-level mathematics course. We believe that these relationships are part of the larger conversation of mentoring in STEMM subjects [71]. Per the National Academies of Sciences, Engineering, and Medicine, effective mentorship primarily includes building supports and trust, openly communicating expectations, as well as engaging in ongoing education and self-reflection [72]. We found in this research study that STEMM faculty mentors and LAs engaged in such reciprocal activities, which led to relationships with learning in four areas: showing care and fostering relationships; honing pedagogical skills; being prepared for class and students; and developing content knowledge in their chosen STEMM area. We believe that it is through these strong and positive relationships that LAs (and also cooperating faculty mentors) engaged in learning [73], with a common cause in supporting undergraduate STEMM learners. We note that the effort and learning is not just one direction, from faculty mentors to LAs. Rather, research suggests that professors who worked alongside LAs had new insights to teaching and learning [45], developing richer activities to enhance student engagement and collaborative learning in their classrooms [30]. Notably, we found a large degree of agreement of this study's findings with current literature, although our STEMM faculty mentors and LAs experienced a rapid transition from face-to-face instruction and mentoring to an all-virtual delivery. Despite this fundamental change in interaction modality, this did not change what mentor faculty and LAs valued and prioritized in their professional, working relationships. Moreover, we are appreciably careful with our language to indicate that LAs who are working in tandem with faculty mentors in LA programs should enhance instruction, rather than supplant or change the professor. We acknowledge that "there is a risk that participating faculty members may feel they are being unfairly categorized as traditional instructors who [for example] solely lecture. Such messages, whether intended or not, can be off-putting to faculty and thus counterproductive to catalyzing change" ([74], p. 625]. Therefore, we echo recommendations made by Sabella et al. [46] and Schick [30] that LA programs should start small, with motivated faculty (serving as faculty mentors) and LAs who are motivated by (per this study) a common goal of showing care and fostering relationships with undergraduate STEMM learners.

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