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"Dear future woman of STEM": letters of advice from women in STEM

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Abstract

Background Although a large body of research has identified challenges faced by women in STEM fields and strategies to improve the experience for women in STEM, little of this research has examined which strategies undergraduate women would recommend to their peers. In the current study, undergraduate women in STEM fields ($N = 89$) wrote letters to younger women in STEM about their experiences. The participants were recruited from a small public liberal arts college and a large public research institution in the United States. Participants were juniors and seniors majoring in engineering, mathematics, computer science, physics, biological or biomedical sciences, and chemistry.

Results Using thematic analysis, we identified seven types of advice. The participants shared advice about improving academically, forming communities, finding family support, and seeking out women role models. They also provided general words of encouragement and reassured women that everyone struggles, and failure is not indicative of their potential. In some cases, the letters were consistent with themes from prior research; however, other influences that have been studied by quantitative research were not prominent in women's own advice to their fellow students. For example, although the letters focused on communal themes such as building community, they did not focus on the communal goal of helping others through their careers. Additionally, they highlighted the role of family, which has been relatively neglected in prior work.

Conclusions The present research highlights which empirically supported theories about retention and success in STEM are reflected in students' advice to others. These letters also provide insight into which obstacles and solutions were most salient for women students looking back on their undergraduate STEM careers. The women's letters provide a rich understanding of how women navigate STEM fields and what they would tell future students about persisting in those fields.

Keywords Women, STEM, Gender, Advice, Discrimination, Community

Introduction

What advice do undergraduate women in STEM think future women STEM majors need? Although a great deal of research has examined the challenges and triumphs of women in STEM (for a review, see Charlesworth & Banaji, 2019), much less research has focused on advice, particularly peer advice for undergraduate women. Examining the advice that women STEM majors would like to give their peers provides insights into the challenges that these women face, the strategies that they recommend for addressing them, and the types of social support that they might provide to one another. The current study examines how women themselves view these issues, how they encourage their peers to cope with or address the obstacles they face, and how their advice corresponds to strategies previous research has proposed to improve the experience and retention of women in STEM.

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Giving advice can be a major component of peer mentoring. Peer mentoring can contribute to women's persistence and success in STEM fields by providing both academic and psychosocial support (e.g., Anderson et al., 2019; Winterer et al., 2020; Zaniewski & Reinholz, 2016). Peer mentoring and advice-giving can occur in a variety of ways. Institutions may provide formal mentoring programs, or students may form connections with others through courses (e.g., more advanced students serving as tutors or teaching assistants) or clubs and organizations (Atkins et al., 2020; Whitten et al., 2003). While formal peer mentoring programs often include training and structured topics of discussion between mentors and mentees, informal helping relationships do not typically have this type of guidance. Rather, peer advice may rely more heavily on students' own personal perceptions or experiences. Both formal and informal mentoring may benefit from understanding which issues are most salient to potential peer mentors. Furthermore, the types of strategies they recommend to address challenges can provide important insights into students' experiences in STEM and may also highlight ways to improve support for women in STEM.

As a backdrop for our study, we first review the types of challenges that women may encounter when pursuing an undergraduate degree in STEM. Next, we consider the ways that previous research has identified to address these challenges and improve retention. Based on these two broad avenues of inquiry, we examine the advice that current junior and senior undergraduate women in STEM provide students who are earlier in their STEM education.

Challenges for women in STEM

Women in STEM face a number of challenges (Dasgupta & Stout, 2014). For example, experiences of gender-related bias and sexual harassment are frequent in the STEM environment (e.g., Aguilar & Baek, 2020; Leaper & Starr, 2019; Robnett, 2016). A negative climate can also include experiences of having one's ideas disparaged or being "mansplained" to by male peers (e.g., Robnett, 2016; Settles & O'Connor, 2014; Settles et al., 2012). "Mansplaining" refers to a man talking condescendingly to a woman, assuming (often incorrectly) that he knows more about a subject than she does (Johnson et al., 2021). Additionally, women tend to have lower confidence or feelings of self-efficacy about their STEM abilities compared to men at the same grade point level (e.g., Cwik & Singh, 2021; Fisher et al., 2020; Marshman et al., 2018; Sterling et al., 2020). For example, a systematic review found that undergraduate women in STEM in Australia showed lower levels of self-efficacy compared to men (Fisher et al., 2020). Even successful women may suffer from imposter syndrome: the feeling that their achievements may not be deserved and that they may be exposed as a fraud (Clance & Imes, 1978; Tao & Gloria, 2019).

Furthermore, introductory STEM courses are typically challenging, and students may receive lower grades than in other disciplines (Rask, 2010). Some of these courses are considered "weed out courses" and can lead to high rates of attrition from the major with women being more likely to leave after receiving lower grades (Weston et al., 2019). Women may be more likely than men to see lower grades as an indication of their lack of ability rather than the challenging nature of the courses. For example, a study of economics students suggested that women are more sensitive than men to receiving low grades in introductory economics courses and will choose to leave the major as a result (Rask & Tiefenthaler, 2008). Importantly, increased departure from the major occurs even for women with relatively good grades (e.g., Bs; Rampell, 2014). Women are more likely than men to leave STEM majors after introductory STEM courses even when they are "high-performing" (Seymour, 2019, p. 439). In addition, women are more likely than men to leave calculus courses, often prerequisites for other STEM courses, due to a lack of math confidence (Ellis et al., 2016).

Left unaddressed, these challenges can lead women in STEM to leave their majors or to have lower aspirations to pursue STEM careers (e.g., Kuchynka et al., 2018; Moss-Racusin et al., 2018). However, many of these challenges can be addressed through social or academic support or reframing (e.g., not viewing a single failed test as a lack of ability to succeed in the field as a whole). Peer advice to help students navigate these situations, seek out appropriate help, or make necessary changes has the potential to be a valuable part of improving women's STEM persistence. Thus, it is critical to identify the advice that women who may have successfully navigated these challenges would give women who are entering STEM majors.

To contextualize the advice from the student perspective, we next briefly review major approaches to attracting and retaining women in STEM. These approaches have focused both on psychological factors influencing students' perceptions of STEM and environments that foster STEM participation and persistence.

Retaining women in STEM

In addition to identifying challenges, research has also suggested ways to improve the experience and retention of women in STEM. For example, one important line of research suggests that women may be more likely to want to pursue communal goals (e.g., Diekman et al., 2015). Such goals may include collaborative rather than individualistic working conditions, conducting research aimed

at societally beneficial outcomes, or balancing work and family. Creating environments that support such goals can improve the retention of women. For some women, their STEM environments are not conducive to the achievement of communal goals, and they choose to leave STEM fields for fields that are more communally oriented (e.g., education). However, students who place a high value on communal goals can benefit from programs that allow individuals to work together in groups or to receive mentoring (Diekman et al., 2015).

Environments that promote self-efficacy and growth mindsets can also help retain women. Individuals who have a fixed mindset believe that abilities (such as intelligence) are innate and unchanging, whereas individuals with a growth mindset believe that abilities are changeable (Dweck, 2008). Individuals with growth mindsets recognize that setbacks are part of learning, and this approach encourages persistence. The mindset of both students and instructors can matter for persistence. In a set of studies on professors' mindsets, students anticipated performing more poorly and having less interest in STEM classes when the professors were described as having a fixed mindset, and this effect was especially pronounced for women (LaCosse et al., 2021). Students in courses with professors with fixed mindsets experienced more negative affect and more impostor feelings, which reduced interest and increased drop-out intentions (Muenks et al., 2020). Similarly, women in an introductory biology course who received growth messages were more likely to sign up for tutoring and had higher grades than those who received only information about tutoring sessions (Covarrubias et al., 2019; Limeri et al., 2020).

Another approach focuses on reducing stereotypes and encouraging feelings of identity and belongingness. Indeed some interventions at the secondary education level focus on developing STEM identity (Prieto-Rodriguez et al., 2020). Negative stereotypes can suggest that women do not have the ability to succeed in STEM, and women may internalize these stereotypes and consequently may not see STEM as part of their identity (e.g., Nosek et al., 2002; Rosenthal et al., 2011; Settles, 2004). Women, particularly those from underrepresented groups, may not feel a sense of belonging in a STEM field (Rainey et al., 2018). Combating these stereotypes can thus help improve the experience of women in STEM. For example, the presence and active involvement of women mentors and role models can play an important role in helping women achieve (e.g., Charlesworth & Banaji, 2019; Herrmann et al., 2016; Lockwood, 2006; Stout et al., 2011), and promoting opportunities for peer networking can increase feelings of belongingness (Dasgupta & Stout, 2014). Increasing feelings of belongingness can be a critical element of an inclusive STEM education beginning at the secondary education level: an investigation of 20 "inclusive STEM high schools" found that an atmosphere of belongingness and a supportive external community were both essential components of inclusive education (LaForce et al., 2016).

Professional advice and support networks can be an important element of career success (Feeney & Bernal, 2010), but there is some evidence that women receive less mentoring than men (e.g., Nolan et al., 2008). Additionally, given gender disparities in the availability of mentors (e.g., the fact that there are fewer women faculty in some fields), the mentoring that women receive may not address gendered experiences. Peer advice may be one way of addressing this potential gap in mentoring.

Present research

Although there is research on problems and solutions for recruiting and retaining women in STEM, there is little research on the actual content of advice that undergraduate women in STEM might provide to their peers. For example, do students themselves recognize the importance of mindset or mentoring, and do they convey this advice to their peers? What other aspects of education or life do students themselves consider important that prior research has not yet uncovered? Examining the overlap and discrepancies between the factors that research has identified as important and what students themselves view as important can provide insights into areas for improvement or formal mentoring.

The advice that women offer highlights what is most salient to them (e.g., Oliver et al., 2017). Therefore, examining this advice can illuminate the lived experiences of women in STEM in ways that go beyond survey or experimental studies. On a practical level, identifying helpful advice from women who have overcome these obstacles could help improve the STEM experience for new majors. Furthermore, while research on obstacles for women in STEM and strategies to improve the climate for women in STEM has provided important advances, these studies often focus on particular issues guided by the researchers' theoretical approach; our study complements this work by examining the perspectives of women themselves. Which strategies stand out most to students as being effective, and what do they recommend to other STEM women? These letters capture women's own voices, and we identified common themes among many unique experiences.

In the present research, we conducted an exploratory qualitative study in which undergraduate women STEM majors in their junior and senior years of college wrote letters about their experiences in their majors to first- and second-year students. The women were asked to describe their struggles, the advice they were given, and what

helped them achieve positive results in their major. We used thematic analysis to identify the kinds of advice they would give to their peers. Given the exploratory nature of the study, there were no a priori hypotheses. However, we sought to address the following research questions:

Research Question 1*: What advice do junior and senior undergraduate women in STEM fields give to students in the first and second years of their STEM majors?*
Research Question 2*: Which pieces of advice were most frequently given?*

Method

Participants

From March 2019 to November 2020, participants were recruited from a small public liberal arts college (with an enrollment of approximately 1,500 students) and a large research university (approximately 32,000 students enrolled), both in the eastern United States. Recruitment occurred via email, flyers, and by announcements to STEM classes. Potential participants were told the following: "We are performing research on how students think about their past experiences in STEM. You will be asked to fill out a survey and to write a letter about your experiences." To be eligible, participants had to be individuals who identified as women, were in their junior or senior year, and were majoring in one of the following STEM fields: engineering, math, computer science, physics, biology, or chemistry. Participants were compensated with $10.00, and the study was estimated to take 45 min. The study was approved by the Institutional Review Boards at both institutions. The target sample size for this study was 100 participants. This sample size was chosen based on the idea that 100 letters would allow us to observe a relatively wide range of experiences as well as practicality (i.e., it was the number of letters we felt we would be able to recruit based on our past experiences recruiting this population). The original goal was to recruit 115 participants to account for excluding ineligible participants. However, due to slow recruitment, data collection ended after 104 participants completed the study. After excluding participants who were not majoring in a STEM field ($n=1$), participants who were not in their junior or senior year ($n=13$), and a participant who identified as nonbinary ($n=1$), the final sample size was 89 participants ($M_{age}=20.94$, $SD=2.31$; 10.1% African American, 21.3% Asian or Asian American, 2.2% Hispanic/Latina, 3.4% Multiracial, 62.9% White). Fifty-seven participants were juniors and 32 were seniors. All the targeted majors were represented: biology ($n=33$), biomedical sciences ($n=2$), biochemistry ($n=8$), chemistry ($n=10$), computer science ($n=10$), math ($n=10$), physics ($n=2$), engineering ($n=10$), multiple STEM majors ($n=3$), and an unspecified STEM major ($n=1$). Thirty-nine of the participants were from the small liberal arts college and 47 were from the large research university. Two participants reported attending a different institution and one participant did not report their institution.

Procedure

The study was conducted online via Qualtrics. After providing consent, participants were asked to write a letter "to first year women STEM majors about your experiences in STEM." The instructions were as follows:

> *It is very important that you take the time to write this letter. We recommend typing it out in a word document and then copying and pasting it into the word box below. We expect that most letters will be at least three paragraphs long and at least half a page single-spaced. When thinking about what to include in your letter, reflect on your experiences in your major. What has gone well and why did it go well? What have you struggled with and why did you struggle? How have you overcome obstacles or challenges? Was there any especially good or bad advice you received along the way? Were there things that professors, friends, family members, or fellow students did that helped or hurt your progress in your major?*

As part of a larger study, after writing the letter, participants completed a set of other questionnaires related to gender and STEM (see materials on Open Science Framework). As these are not the focus of the present study, they will not be discussed further. Participants also completed demographic questions (age, gender, race/ethnicity, year in school, college, major, GPA in major).

Theme identification and coding process

We used a coding reliability thematic analysis (Braun & Clarke, 2006, 2022) to identify the themes and then had coders identify which themes were present in each letter. For theme identification, we followed the procedures outlined by Braun and Clarke (2006). The initial research team was composed of two principal investigators and three undergraduate research assistants. First, each member of the research team read all the letters and identified their initial codes (i.e., key pieces of content that appeared across multiple letters). Next, the team members met and shared their codes and discussed commonalities among the codes. The principal investigators then met separately and decided upon a set of themes based on these initial codes and created a codebook for these themes.

For the coding process, one of the principal investigators met with the two coders (i.e., two of the research assistants, "Pair 1") and explained the codebook. The two coders completed a training round of coding on a set of ten randomly selected letters. Then the two coders met with one of the principal investigators to discuss discrepancies and clarify the codebook. After this round of clarification, the two coders completed a second training round with a new set of ten randomly selected letters. Then the coders both coded the rest of the letters. Our goal for inter-rater reliability was for all Cohen's kappas to be greater than 0.50 and for the percent agreements to be greater than 80%. The coders reached acceptable inter-rater reliability for nine of the 13 categories (all $\kappa > 0.55$, all percent agreement > 80%, see Table 1, Pair 1). The coders resolved discrepancies for these categories via discussion.

The coding for Empowerment and Perseverance ($\kappa = 0.42$, 73.8% agreement) and Everyone Struggles ($\kappa = 0.34$, 82.1% agreement) did not reach our threshold for inter-rater reliability. The two PIs met with the two coders to discuss these themes. The two coders redid their coding for the three remaining themes, but the inter-rater reliability did not increase upon re-coding (Empowerment and Perseverance $\kappa = 0.44$, 71.4% agreement; Everyone Struggles $\kappa = 0.47$, 84.5% agreement). Therefore, two new coders (an undergraduate student and a postdoctoral research assistant) joined the research team ("Pair 2") and were trained on these final two categories using the same method as noted above for training and coding. The coders achieved acceptable inter-rater reliability for Everyone Struggles ($\kappa = 0.64$, 83.7% agreement). Empowerment and Perseverance did not reach our target kappa ($\kappa = 0.47$, 82.7% agreement), but given the multiple rounds of coding and the percent agreement, we decided to move forward with that category. However, given the level of inter-rater reliability, the results related to Empowerment and Perseverance should be interpreted with caution. Discrepancies for these categories were resolved via discussion. All four coders were asked to disclose their salient identities that may have shaped their coding responses, and those identities are reported in Table 2.

Results

In our initial thematic analysis, we identified two broad themes across the letters: struggles and advice. For the purposes of the present article, we focus specifically on the broad theme of advice (and the subcategories of that theme) and not on the theme of struggling in the major. Participants reassured younger women and imparted valuable academic and social advice (see Table 3 for frequencies). They communicated this advice both directly by addressing the reader and indirectly through anecdotes. Participants encouraged their readers to seek support from professors, teaching assistants, academic advisors, and tutors to improve their academic performance. Further, their academic advice included suggestions for studying more effectively and building time management skills. Many letter writers also emphasized the value in forming communities with peers. Participants expressed that these communities could serve as academic, professional, and social support networks. Smaller groups of participants suggested that women mentors and family members could act as other sources of academic and social support for women students in STEM. Finally, participants offered their reader congratulations and other words of encouragement.

Everyone struggles

Although the letter writers wrote about their struggles, 40.4% underscored that struggles and failure are normal. They normalized academic setbacks, such as failing classes and tests and struggling with assignments and course material. For example, a White senior biology major at the large public institution wrote that retaking difficult STEM courses is not at all unusual, especially in her own experience:

Table 1 Interrater reliability for coding themes

Theme	Coding pair	Cohen's Kappa	Percent agreement (%)
Everyone struggles	2	0.64	83.7
Failure not indicative of character	1	0.88	97.6
Academic advice	1	0.63	81.0
Form community	1	0.67	88.0
Women role models and mentors	1	0.84	95.2
Family support	1	0.84	95.2
Empowerment and perseverance	2	0.47	82.7

Table 2 Percent of theme endorsement by each coder across all letters and salient identities of coders

	Coder 1	Coder 2	Coder 3	Coder 4
Identities	White heterosexual woman, age 21, senior undergrad in psychology, transfer student, commuter	White heterosexual male, age 21, junior/senior undergrad in psychology	White heterosexual woman, age 21, junior undergrad in psychology, has taken courses in data science and math, has TAed research methods and statistics, has invisible illness	White heterosexual woman, age 31, research assistant, PhD in Communication, MA in Theatre Education
Form community	67.31%	70.19%		
Family support	25.00%	20.19%		
Role model	17.31%	19.23%		
Empowerment	67.31%	62.50%	94.00%	70.19%
Academic advice	48.08%	59.62%		
Failure not characteristic	11.54%	11.54%		
Everyone struggles	14.42%	24.04%	42.31%	25.00%

Coders 3 and 4 only coded for the categories that did not reach sufficient agreement by the first two coders. The percentages reported are for all letters ($N = 104$)

Table 3 Descriptions, examples, and frequencies for each of the coded themes

Theme	Example descriptions from codebook	Example from letters	Frequency	Percent (%)
Everyone struggles	These classes are hard for everyone Everyone gets stressed All of my friends had trouble in this class	"Everyone struggles with certain things and you aren't alone in that."	36	40.4
Failure not indicative of character	Failing doesn't make you a failure One bad grade doesn't define you	"There's nothing wrong with you if you fail a class"	11	12.4
Academic advice	Tips about studying; time management Talking to TAs/professors; office hours Doing practice problems Don't be afraid to change majors	"…study as you go, and don't cram!"	45	50.6
Form community	Forming study groups, joining clubs Finding "your people" Connecting with others	"…join clubs and organizations so that you can form supportive groups."	62	69.7
Women role models and mentors	Impact of women professors Seeking out women mentors Seeing women as role models	"I look at my female professors and am inspired"	15	16.9
Family support	Talking to family members Encouragement from family Advice from family	"My mom once told me that when life feels messy its [*sic*] like a house being built, it's jus [*sic*] on its way to a more beautiful home."	23	25.8
Empowerment and perseverance	Overcoming adversity; staying motivated Inspirational advice (stick with it, you've got this) Overcoming difficulties in particular courses Passion for the field Congratulating them; cheerleading	"Don't give up, find what motivates you, find what makes you happy, relieve stress and keep moving forward. The journey won't be easy but girl, you got this."	76	85.4

The most important piece of advice that I will give is that it is okay to not do well the first time around. Everyone will have that one class that they struggle so hard with grasping, even when they put in the hours...I have retaken at least 6 classes in my undergrad, along with so many other students. It is totally normal, so never feel ashamed of it.

By sharing that "everyone" or "so many other students" face challenges, this participant conveys to the reader that she is not alone in any struggles she may experience. A White senior mathematics student at the large university echoed this language in her letter: "For those that need to hear it—you are not alone. Everyone struggles in some of their classes, and some more than others, maybe for

reasons unrelated to school, and THAT IS OKAY." This woman similarly communicated that academic struggles are common among all undergraduate students. She also added that students may struggle in their academics due to challenges outside of the academic setting. Regardless of the root of those struggles, both participants stressed that there is nothing wrong with struggling.

Other participants spoke more to the psychological struggles that "everyone" grapples with, such as anxiety, loneliness, confusion, and self-doubt. A White junior biology student at the liberal arts college wrote: "If you feel confused about college, anxious, or lonely, that's probably because mostly everyone else feels the exact same way especially if it is their first year. So, you're not doing anything wrong." Likewise, reflecting on a summer internship she completed, a White senior physics student wrote that "everyone doubts themselves in a new situation." These accounts suggest to the reader that psychological struggles, like academic struggles, are common and nothing to be ashamed of.

A multiracial junior physics major addressed this theme differently in her letter. Rather than directly reassuring her reader that struggles are normal, she wrote about how engaging with other students in dialogue about struggling normalized her own challenges:

> *Any time someone else talks about how they are struggling with something it makes me feel better/ normalizes the challenges of learning which is good. I try to be light but open about having problems with my classes to provide the opportunity for other people to share/feel more comfortable.*

By sharing how she herself has benefitted from open conversations about struggling, this woman encourages students to be transparent with each other and, therefore, to continue normalizing struggles and failure in STEM fields.

Failure is not indicative of character

A small number of participants ($n=11$) also normalized failure in STEM by expressing that failure is not indicative of one's character or potential. Specifically, participants wrote that failing in classes or on exams and assignments does not make one a failure. A White junior biology student at the liberal arts college, for example, asserted:

> *...FAILING AN EXAM DOES NOT MEAN YOU ARE A FAILURE. I'm going to say it again for my ladies in the back, FAILING AN EXAM DOES NOT MEAN YOU ARE A FAILURE. Learn it and learn it quick because you will fail at least one exam. It doesn't mean you're dumb, and will fail the class, and not get into graduate school, and fail out of college, and end up living in your parents' basement. You will be fine, you can still do well in the class. One mistake does not define you.*

Although this woman expressed that failure is inevitable, she was adamant that mistakes neither reflect one's character nor condemn one to greater failures. Furthermore, she reassured the reader that failure does not preclude success. In the words of a White senior biology student at the liberal arts college: "…that D on a quiz won't ruin your life." Despite receiving a low grade on an assessment, that student went on to a job at a national zoo, demonstrating that that failure was not representative of her capacity to succeed. Accordingly, she recommended taking failure in stride. A third biology student, also a White junior student at the liberal arts college, offered similar insight in her letter: "It is ok if you fail a class. You can retake the class or possibly take it at a community college or another college. There's nothing wrong with you if you fail a class." This student likewise communicated to the reader that failure does not define her. She also suggested that failing a class is not indicative of her reader's potential to succeed in the future, as there are options available for students, such as retaking a class, to improve their performance. Similarly, an Asian American junior computer science major described struggling as a signal to get support rather than as a signal that one is incapable: "I realized that it is not about whether you are good enough or not, it is about you seeking for guidance and help." Although students who wrote about failure not being indicative of character did not necessarily use the language of "growth mindset", they did acknowledge the idea that people can improve over time, and one chemistry student reminded the reader that failure is "a part of growth".

Academic advice

Half of all participants in the study ($n=45$) advised their reader on how to succeed academically in their STEM field. Their letters described practices students should adopt and ones they should avoid. For instance, multiple students recommended that students reach out to professors, teaching assistants, advisors, and tutors to address their academic struggles and strengthen their understanding of the course material. They also underscored the importance of attending professors' and teaching assistants' office hours to develop relationships with those individuals and find opportunities in the field. For example, an African American junior computer science major stated that she "cannot stress office hours enough" while acknowledging that students may not always want to attend them and that

she felt "scared to go…but the TAs are helpful and do not make fun of you at all." A White junior biochemistry student at the liberal arts college firmly advocated interacting with professors:

> *Don't be shy to talk to your professors after class, to attend their office hours, to ask about their research. Most of our professors have a huge passion for teaching and helping students like you, so they love it when they get to talk with you one-on-one instead of just lecture you in class. By getting to know your professors early, you are opening the door to later research opportunities, mentorship, and letters of recommendation. I cannot overemphasize how great an opportunity it is to have relationships with your professors!*

This woman recognized that other students may be apprehensive about reaching out to their professors and, consequently, reassured them that professors enjoy helping students learn and grow in the field. Further, she highlighted how professors can be an asset in both the short term (i.e., in class) and long term (i.e., during subsequent semesters or after graduation). An African American senior biology and math major who discussed the importance of connecting with faculty offered a caveat: "make strong connections with professors who have morals that you agree with. These strong relationships give you somewhere to go when you struggle as well as provide lots of academic experiences and guidance."

Participants also wrote about effective methods for studying independently. Several women advised students to plan ahead in order to best manage their time outside of class. One biology student, a White junior at the liberal arts college, for example, shared: "keeping a well organized planner has really helped me stay on top of things." Other students recommended studying throughout the course rather than simply before the exams, and a White senior biology student at the large university wrote:

> *If I could do it all again, I would study as the course went on. I would do a little bit everyday [sic] and grasp the concepts as we go. This might sound cliche, because this is what most professors tell you, but they're right! I am paying thousands and thousands of dollars for what? A degree? Sure a degree, but what I realized matters more than a degree is learning. When you study right before an exam and cram, you don't remember any of that information past the exam…It will be more beneficial to just actually learn the material, rather than just go for the A.*

In her account, this student explains how consistent studying is advantageous not only for exam performance, but also for sustained learning and getting the most out of one's undergraduate education. This account also addresses an ineffective studying method that students should avoid: cramming, or last-minute intensive studying. A third biology student, who was also a White junior at the liberal arts college, likewise warned students that cramming is not sustainable as classes become more challenging and shared how she adjusted her study methods to accommodate those higher-level classes: "[Cramming] no longer worked after my freshman year. For my upper-level classes I would rewrite my notes every week and start studying those notes at least a week before my exam."

Other participants suggested specific techniques, like rewriting one's notes, for better engaging with the course material. A fourth biology major, a White senior at the large university, remarked:

> *When you study, make sure to learn how to study effectively and don't just stare at your notes hoping that the information will make its way into your brain! Quiz yourself, make summary sheets, color code, do whatever works for you that keeps you engaged in the material.*

The letters within this theme suggest that by inviting academic assistance, regularly studying, and actively engaging with the course material, students in STEM can achieve success and deeper learning.

Form community

A key theme that emerged in a majority of the letters was advising women to form communities with others. Approximately 70% of the participants ($n=62$) encouraged students to connect with others at school and build relationships. A White senior biochemistry student at the liberal arts college wrote that forming communities is critical for succeeding in STEM: "Overall, I personally believe that having people routing [*sic*] for you is vital to being able to be successful in a STEM oriented major." Similarly, a White junior chemistry student at the liberal arts college wrote: "The communities I surround myself with pick me up when I fall."

Participants frequently suggested that students join clubs and form study groups to forge those connections and reported benefiting both academically and socially as a result. For example, one African American senior engineering major provided the following "closing advice" in her letter: "join clubs and organizations so that you can form supportive groups. There are organizations all over campus." Similarly, an Asian American junior computer

science major suggested joining clubs both within and outside the major:

> *Outside of classes, there's a lot to get involved in. It's certainly useful (and fun) to join any clubs (whether it pertains to your major or not) because you get to meet so many people. If the club does pertain to your major, it's helpful to get connected with your fellow peers (especially upperclassmen) who can often give you good advice regarding college and/or career paths.*

Communities of peers were cited in the letters as a great source of support for women in STEM. They held students accountable for their academic responsibilities and facilitated studying course material. Women also wrote that peers endorsed their research goals and encouraged them to build further connections in their department. One White junior biology major at the liberal arts college spoke to these academic benefits:

> *It's helpful to have friends in your major. They are your lab partners, remind you about assignments, talk about your research, get you more involved in the department. Being friends with the professors is almost equally helpful.*

She also suggested that communities at college need not consist of only peers. In fact, professors may fit into these communities as well and provide similar benefits. Other women encouraged students to connect with peers to foster collaboration within fields that tend to be highly competitive. They warned that a competitive mindset is more detrimental than helpful, as it discourages women from seeking support from their peers. Another White junior biology student at the liberal arts college wrote:

> *Focus on doing your best and use your classmates to help you study. Make your peers your allies, not your competition. This will especially become important as you progress in your major because these allies will then be the ones notifying you of research opportunities, club meetings, and professor gossip.*

Like the previous letter, this letter addresses how peers can provide academic support and promote participation in research and the major. The writer also implies that peers are essential sources of information within one's department.

While connecting with peers in general conferred benefits to women students, forming a group of women peers was an especially important source of social support for participants who felt unwelcome in men dominated fields. Multiple students stated that women's support made them feel heard, understood, and respected in the face of gender discrimination. A White junior biology student at the large university, for example, commented:

> *Something that has gone well in my experience of being a stem major was the female friends I've made along the way. I feel like we've each had our own struggles in the major and could relate to one another better than anyone else could. We've studied together, struggled together, and most importantly—succeeded together.*

Participants found that the communities of women they formed were not only supportive, but also empowering. One participant, a multiracial junior chemistry major, even went so far as to compare the community of women within her major to a group of superheroes: "I found some other cool women in my major, and we created like the female avengers of chemistry, and helped each other out when we struggled." Drawing on the encouragement from other women in STEM, participants were able to overcome their struggles and excel in their fields.

Women role models and mentors

In addition to suggesting that women students connect with women peers, some participants ($n=19$) recommended finding a woman role model or mentor in STEM. For several students, having a woman role model in a field dominated by men provided academic and emotional benefits. Participants reported that having a woman as a resource in their department made them feel more comfortable asking for advice and sharing experiences of gender discrimination. According to a White senior computer science student:

> *The computer science department also has had a few female professors, including my advisor, which has been really helpful to me to feel like I have someone to talk to if I ever get uncomfortable, or need advice. She has been there with me from the start and works with me to help propel other women in the major forward and find new opportunities.*

This student's account speaks to how women mentors can be an ongoing source of guidance and support for younger women in STEM. It also communicates to the reader that women professors and professionals make themselves available as mentors.

Participants' interactions with women role models and mentors helped combat their insecurities and increase their confidence within their field. A White junior student in an unspecified STEM major at the large university wrote about how correspondence with her advisor improved her confidence in her ability to navigate academia and the professional world:

Overall, my experience has definitely been on the positive side, and I attribute a lot of that to some really fantastic professors! My advisor, Professor [Name], is a woman in STEM herself and has always pushed me to find confidence not just in my academic abilities, but all of the intangible skills that I will need when I enter industry (such as networking, expressing myself and lending my voice in a group setting with confidence, and not backing away from a challenge even if others do not always support me too).

Thanks to her advisor's guidance, this student felt prepared to pursue a career in her field and take on future challenges.

Multiple letters also described stories of how women faculty members and older women students supported and empowered young women in STEM in the face of gender discrimination. A White junior biomedical sciences student at the large university, for instance, wrote:

...there have also been times where I have been told to rethink my path to medicine because I am a woman. I have been told that I will be constantly torn between work and home if I have a family in the future...These comments have sometimes gotten the best of me and made me truly think about whether or not going into medicine is the right fit for me, considering that I envision myself having a family in the future. However, I have heard from strong women through [name of club] about how you truly can make it work if you want to have it all. You don't have to settle for being an average doctor or scientist because you are a woman and a mother. Instead, you can be great, if not extraordinary at both.

When this student began to doubt her career path in response to discriminatory remarks, it was her women role models that lifted her up and assured her she could succeed in both the professional and domestic setting. Another student, a White junior chemistry major at the liberal arts college, shared that women mentors were a critical source of support following gender discrimination by a professor in a laboratory course:

[Our professor] listened without judgement, and, at her encouragement, we each brought our story to the Title IX office, where we spoke with yet another woman who believed us, supported us, and treated us with compassion and respect. That response more than restored the confidence I had lost throughout the weeks of conflict...

Due to the unwavering support of women mentors, this student was able to move past this distressing episode. In fact, she wrote that "the generosity of that support remains far more important in my mind than the original conflict," thereby revealing just how great of an impact women mentors had on her academic experience.

Family support

Support networks did not exist merely within the sphere of academia. As 26% of participants ($n=23$) reported, family was also an invaluable source of support. Family members supported women students in various ways and were therefore critical to their journey in STEM. For instance, several participants wrote that parents and siblings shared advice that motivated them and helped them overcome adversity and self-doubt. According to a White junior biology major at the liberal arts college:

I think that the best advice I have received throughout my college career so far is from my parents and they always tell me to, "take my time and do not rush through my major, go at your own pace, take a gap year if you want to, take an extra semester if you need to but in the long run not being at the same pace (especially in premed) as everyone else will NOT impact you so do not lose sleep over it."

In moments of intense stress, her parent's guidance "ground[ed]" her and reminded her to "be happy with [her] own progress instead of worrying about anyone else's." Another biology major, an African American student at the large university, shared her mother's encouraging words, which emphasized the impermanence of struggles: "My mom once told me that when life feels messy its [*sic*] like a house being built, it's jus [*sic*] on its way to a more beautiful home." As for one Asian American engineering student at the large university, it was her brother's advice that resonated with her when she struggled. She wrote: "My brother has always been encouraging. He always says, 'If you never try, you never know. You got nothing to lose.'" His support gave her the confidence to ask questions and seek out opportunities in her field.

Other participants wrote that their family members were simply "there for" them. For example, a White junior biochemistry student at the liberal arts college wrote:

My parents have been my biggest help throughout my entire college career. The past 2 and half [sic] years have been extremely tough and I do not think I would have gotten through them without my mom and dad. They have always been there for me from the highs of acing an exam to the lows of failure and self-doubt.

Her parents' consistent presence served as a reminder that she would never have to "feel [her] failures alone,"

which "motivated [her] to keep going." A White junior engineering major at the large university used similar language to describe her parents' support of her: "Keeping in touch with my parents was the biggest thing that helped me through everything." Her account reveals just how indispensable family is as a support system. Beyond providing support, family members also provided students with inspiration. For example, one student, an African American senior biology major wrote about how she struggled with "being taken seriously" but that she received advice from her grandmother that "the struggles will make the victory even more worth it." Acknowledging the limits of family help, an Asian American junior chemistry major at the large university shared how important their encouragement can be: "No, your friends or family may not be able to walk your path for you or solve problems for you but they will always be there by your side. That simple thing will help you carry on." While family may not necessarily provide practical support, familial emotional support was valued by these students.

Empowerment and perseverance

The most common theme across participants' letters was Empowerment and Perseverance, with over 85% of letters ($n=76$) including inspirational, motivational, or congratulatory messages. Recognizing the diligence and dedication it takes to pursue a degree in STEM, numerous participants expressed that students should be proud of the work that they do. A White junior chemistry student at the liberal arts college affirmed: "Love yourself! You're a STEM major and that's incredible!" This student also encouraged students to persevere so that they might succeed in their field: "Keep doing what you're doing and you'll get where you want to go." Finally, she concluded her letter by voicing her support for the reader going forward: "I wish you the best of luck (even though you won't need it)." In addition, letter writers congratulated students for making it to college and for deciding to study in a STEM field. For instance, a White junior math student wrote, "Congrats on picking such a fun field to immerse yourself in!" and a multiracial junior chemistry student wrote, "First, off, congratulations! You've made it to college, and you've chosen an incredible field to go into." These congratulatory remarks draw the reader's attention to how fun and exciting STEM can be.

Other letters offered the reader empowering messages about overcoming adversity. For example, multiple participants pushed students to remain positive in the face of gender discrimination. A White junior biology student at the liberal arts college wrote:

> *Know your worth, know you worked your ass off to get to where you are. Not all men will [mansplain or underestimate you] but there will be some. Speak up, be proud, and don't be afraid to make mistakes.*

This affirmation serves as a reminder to the reader that her worth is independent of men's opinions of her and that she has earned her place in the field. Several participants also wrote empowering words about prevailing over difficult coursework. A second White junior biology student at the liberal arts college emphasized that earning a STEM degree is worth the academic challenges:

> *Being a STEM major, especially a biology major, has its ups and downs, but I can promise you that it will all be worth it when you walk across that stage with that diploma in your hand!*

By reminding the reader that her hard work will ultimately lead to achieving her goal, this student encouraged her to persist through those challenges.

Another way that participants empowered students was by sharing their own inspirational stories. A White senior engineering student at the large university wrote:

> *I learned quickly that an engineering degree was extremely demanding, and I wondered if I picked the right path...However, I persevered and made sure to receive grades I was proud of. Luckily, all my hard work paid off. Recently I was accepted into a PhD program at a graduate school of my dreams. Looking back, I am glad I spent all that time working, because if I did not, I would never had [sic] ended up where I am today.*

Through this success story, this student demonstrated to her reader that persevering through challenges and moments of uncertainty can be incredibly rewarding. For another biology major, an Asian American junior at the large university, it was passion that drove her to reach her goals:

> *Coming to [school], I realized how many students wanted to pursue a degree in the medical field. This made me very nervous and anxious about how I was not going to make it, but something in me kept me going. It was passion! From the very start, I had a passion for helping out people through my knowledge and make them feel comfortable. My passion had driven me to finish this path that I chose to take!*

Her account's emphasis on passion inspires students to focus on their love or excitement for their field rather than their anxieties about mistakes and failure. In many cases, despite the struggles and obstacles that writers described, their ultimate messages were of support and

perseverance. These women encouraged their younger peers to stick with it and be proud of how far they have come even in the face of discrimination and other challenges, both academic and psychological. As one woman, a White senior computer science major at the large university, wrote, "your persistence is what makes it possible to increase the number of women in the field." These women know the struggles that younger women in STEM have and will continue to encounter. They continue to pave the road so it will be that much easier for the next woman, and they encourage their younger counterparts to do the same.

Discussion

This qualitative study provides important insights into the types of advice that STEM women are likely to provide to their peers. The responses highlight the central role of community and social support, including the role of family support. Beyond presenting specific advice, the letters themselves enacted social support by providing encouragement and motivational messages.

The findings from the study expand understanding of the features of their experience that are most salient for STEM women. In some cases, the letters were consistent with themes from prior research, but other influences that have been studied by quantitative research were not prominent in women's own advice to their fellow students. For example, some of the themes focused on the communal goal of working with others by developing relationships with peers, finding role models, and finding one's community (e.g., Dasgupta & Stout, 2014; Diekman et al., 2017; Fuesting & Diekman, 2016). Yet, students in the current study did not frequently mention the role of another major communal goal: helping others. STEM fields are often stereotypically perceived as not affording individuals the opportunity to engage in helping behaviors or solving societal issues, which can be a factor in reducing the recruitment and retention of individuals who more strongly endorse communal goals (Diekman et al., 2010, 2011). This discrepancy may indicate an area where intervention may be particularly fruitful. Peer mentors may not generally think in terms of broader goals and values, so interventions that help students clarify their larger goals and map these goals to their majors and future careers may be a valuable addition to mentorship.

Although explicit consideration of helping goals was not common in the sample, it was not completely absent. One student, an Asian American senior math major, did note the clash of values she experienced in studying math that led her to reconsider graduate studies:

> *But ultimately what did me in was a difference in values between me and STEM culture. We're supposed to not care about social issues, because if we don't ask where the bombs we build are being dropped we'll keep building them.*

If this student's field had placed more emphasis on the communal goal of helping others, she may have continued her initial path of study.

Two of the other advice themes broadly connect to the idea of communal goals: family support and empowerment. Although family support is not featured prominently in the psychology research on women in STEM, family support has been shown to be critical to student success in a study on STEM students at a Hispanic-serving institution (Talley & Martinez Ortiz, 2017). Thus, it will be important to continue to understand the role of family support at different types of institutions and among different populations of students. For example, for which students or which STEM contexts may peer support versus family support be more beneficial? Furthermore, what does helpful family support look like? STEM interventions often focus on the student themselves or on resources provided within an educational context, but our qualitative results suggest that it is important to consider broader social structures as well.

The empowerment theme did not include directly advising individuals to connect with others or receive support (which were captured in some of the other themes, such as "form community"), but rather, it embodied the concept of social support. That is, the messages that the participants provided within that theme were examples of the writers themselves giving social support to the letter reading audience. Thus, they were providing a type of communal support and connection to their readers.

In addition, the letter themes about how everyone struggles and that failure is not indicative of character were consistent with work on growth mindsets in STEM. Letter writers encouraged their readers to accept that failure is part of the learning process and not to attribute failure to deficiencies in one's intelligence or potential. Much like the advice about finding role models and community, this advice has empirical support: both professors' and students' beliefs about growth mindsets can affect women's performance and belonging in STEM fields (e.g., Covarrubias et al., 2019; Good et al., 2012; LaCosse et al., 2021). Our findings complement this perspective by providing insight into how women students themselves think and talk about overcoming struggles.

Although the two themes mentioned above were broadly consistent with work on growth mindsets, the

letters particularly highlighted an element which is less often emphasized in mindset interventions: the idea that everyone struggles at some point. Helping women students understand that difficulties in STEM courses are common can help change their attributions about their own difficulties and improve achievement (e.g., Walton et al., 2015; Yeager et al., 2016). A student who sees that others have had difficulty with STEM courses but have coped with those challenges and succeeded may be less likely to attribute their own difficulties to a lack of ability. In other words, students with stronger growth mindsets about others may respond differently than students with stronger fixed mindsets. In a study of physics students, growth mindsets about the self and others decreased over the course of a semester for women but not as much for men (Malespina et al., 2022), indicating a potential gender-related issue with how individuals are viewing norms related to growth and ability. Our results suggest that the social or normative element is important in encouraging these mindsets; the letters focused on the fact that failure and improvement are common experiences, rather than focusing on understanding individual psychology alone.

Although some aspects of the letters were particularly focused on the gendered aspects of being a woman in science (for example, the experience of feeling underestimated because of one's gender), other elements of the advice that students provided could be applicable to any STEM student. For example, many letters provided practical advice about going to office hours, using effective study strategies, or finding tutors. Thus, while women in STEM recognize that they may have unique challenges, they also highlight the benefits from general academic support.

In addition to the opportunity to observe which empirically supported theories about retention and success in STEM are reflected in the students' advice to others, these letters also provide a rich understanding of which obstacles and solutions were most salient for women students looking back on their undergraduate careers. This qualitative work provides an important complement to experimental investigations of individual theoretical approaches (e.g., Atkins et al., 2020).

Limitations

There were several limitations in the present research. First, although the categories for identifying advice were comprehensive, not everything that participants wrote clearly fit into a category. Second, although we used a rigorous process for coding and attempting to achieve high inter-rater reliability, the inter-rater reliability for Empowerment and Perseverance remained low, and those findings need to be interpreted with caution. Furthermore, our coders identified as White, heterosexual individuals who came from psychology and communication academic backgrounds. Thus, the coding results may have differed with a different group of coders coming from more diverse racial, sexual orientation, and academic backgrounds.

Our findings may also be limited in their generalizability, as we sampled from two public institutions in the United States (one small liberal arts college and one large research university). Not all STEM fields were equally represented in our sample, and only engineering, math, computer science, physics, biology, and chemistry were represented. The sample was also skewed toward White women and is not necessarily representative of other races or ethnicities. Therefore, we are unable to examine how patterns of advice may vary across races or ethnicities. However, we think this is an important avenue for future investigation. For example, a preliminary examination of the data indicates that White students may be overrepresented in the categories of role model and empowerment. It will be important for future research to dig more deeply into these potential differences and examine whether they are reliable and whether they depend on the ways in which the themes are conceptualized. Finally, we recruited only students who were willing to write a letter, and these students may differ from those who did not wish to detail their experiences or share advice. Despite these limitations, our findings provide detailed insight to the experiences of women STEM majors and point to future directions for further exploration and ways to help these undergraduates in their academic and psychological struggles.

Finally, although these letters captured women's own impressions, the women may not have been aware of subtle factors in their environment that might have helped or hindered their performance. These letters may reflect individuals' intuitive theories about what matters, and thus may not provide a full picture of the elements that influenced their experiences.

Future directions

The current results provide a foundation for investigating questions that have been relatively unexplored in existing quantitative studies of women in STEM, such as the role of family support and the social aspects of encouraging growth mindsets. Additionally, future work can apply the knowledge gained from the current studies. Previous research has found that women peer mentors can increase the persistence of women in STEM fields, in part by encouraging mentees' confidence and sense of belonging (Dennehy & Dasgupta, 2017). Furthermore, letters from women role models have been shown to increase course performance for women in introductory psychology and chemistry courses (Herrmann et al., 2016). Thus,

letters from women peers might serve a similar purpose, and a major goal of this work is to use these letters as interventions to help first- and second-year women in STEM persevere in their majors. One way to do this may be sharing letters directly or combining representative sections from several letters into one meaningful set of experiences and advice. It may also be helpful to compile advice into a handbook for future students, pairing stories of struggle with respective areas of support and encouragement.

Further exploration in this area might more directly compare the advice from different groups of students. In doing so, we might also investigate which types of advice are most useful and for whom. For instance, women from historically underrepresented racial groups mentioned additional discrimination based on their race, and it would be worthwhile to explore these intersectional experiences along with more tailored support structures. Additionally, students in different STEM fields may offer different forms of advice: the strategies that work for finding one's community may differ for a woman in biology compared to a woman in computer science. Furthermore, future research can also consider how advice might differ across genders or across different non-STEM fields.

Our study also included only students who continued in a STEM major. Future research might compare the experiences or advice of students who stayed in a STEM field versus those who switched to a different field of study. This comparison might help identify additional areas for future interventions.

Additionally, previous research suggests that giving advice may provide benefits to the advice-giver (Eskreis-Winkler et al., 2019). Although the present research did not examine the effects of writing the letter on the participants' experiences in STEM, future research can assess whether providing advice to newer students might have psychological benefits for more advanced students, or whether it might be an effective way of building relationships between cohorts of students. It would also be important to consider whether the tone of the advice impacts the advice-giver. The letters in the present study varied considerably in terms of how positively they felt about their experiences in STEM, and it is likely that the experience of writing these letters was markedly different for participants who were sharing positive versus negative experiences and pieces of advice.

Furthermore, we did not want to place tight constraints on the letters that the participants wrote, so they were asked broadly to write about their experiences in their letters to first year women in STEM. One avenue for future research could be to examine how advice may change if participants are specifically instructed to only provide advice. It is possible that when the advice is decontextualized from their specific experiences, they may emphasize different forms of advice.

Finally, it is important to note that even though our analyses highlight advice and some of those pieces of advice were motivated by negative experiences, not all experiences were negative. Many women recounted positive experiences as STEM majors, such as building close friendships, having passion for their field, and a strong sense of pride from personal and academic growth.

Conclusion

We encourage further exploration of women STEM students' experiences, needs, and ways to support the academic journeys of the next generation of STEM scholars. In closing, we share a message of hope from the same participant who noted the potential ethics value clash: "I hope you do well, learn a lot, and I hope that you can do more to build community and help each other than I could. I tried my best, but you always hope that the next cohort does better."

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Author contributions
G.F. and M. C. G. conceptualized the study, created the materials, oversaw the coding process, analyzed the data, and wrote the paper. M. K., M. D., and M. M. M. authors coded the data and wrote the paper. All authors read and approved the final manuscript.

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Availability of data and materials
The letters written for this study are not publicly available as they contain information that could identify participants. The coded data and the materials for the study are available at https://osf.io/975pa/.

Code availability
The code is available at https://osf.io/975pa/.

Declarations

Ethics approval and consent to participate
The research was approved by the St. Mary's College of Maryland IRB (SP19_33A) and University at Buffalo's IRB (STUDY00003331).

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The authors have no potential conflicts of interest to declare.

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