frontiers in Education

PERSPECTIVE
published: 22 February 2021
doi: 10.3389/feduc.2021.639338

What Questions Are on the Minds of STEM Undergraduate Students and How Can They Be Addressed?

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OPEN ACCESS

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Specialty section:
This article was submitted to STEM Education, a section of the journal Frontiers in Education

Received: *08 December 2020*
Accepted: *20 January 2021*
Published: *22 February 2021*

Citation:
Meaders CL, Smith MK, Boester T, Bracy A, Couch BA, Drake AG, Farooq S, Khoda B, Kinsland C, Lane AK, Lindahl SE, Livingston WH, Bundy AM, McCormick A, Morozov AI, Newell-Caito JL, Ruskin KJ, Sarvary MA, Stains M, St. Juliana JR, Thomas SR, van Es C, Vinson EL, Vitousek MN and Stetzer MR (2021) What Questions Are on the Minds of STEM Undergraduate Students and How Can They Be Addressed?. Front. Educ. 6:639338. doi: 10.3389/feduc.2021.639338

Addressing common student questions in introductory STEM courses early in the term is one way that instructors can ensure that their students have all been presented with information about how to succeed in their courses. However, categorizing student questions and identifying evidence-based resources to address student questions takes time, and instructors may not be able to easily collect and respond to student questions at the beginning of every course. To help faculty effectively anticipate and respond to student questions, we 1) administered surveys in multiple STEM courses to identify common student questions, 2) conducted a qualitative analysis to determine categories of student questions (e.g., what are best practices for studying, how can in- and out-of- course time be effectively used), and 3) collaboratively identified advice on how course instructors can answer these questions. Here, we share tips, evidence-based strategies, and resources from faculty that instructors can use to develop their own responses for students. We hope that educators can use these common student questions as a starting point to proactively address questions throughout the course and that the compiled resources will allow instructors to easily find materials that can be considered for their own courses.

Keywords: undergraduate, introductory STEM courses, questions, academic success, time management, studying, self-regulated learning

1 INTRODUCTION

Compared with high school, the structure of college science, technology, engineering, and mathematics (STEM) courses requires students to engage in more independent and self-regulated learning outside of class (Akiha et al., 2018). This shift in learning strategies can be challenging for first-year students (Fazey and Fazey, 2001; Christie et al., 2016). Corresponding increases in student concerns, perceptions of course difficulty, and general class anxiety are inversely correlated with academic performance (England et al., 2019; Meaders et al., 2020; Lane et al., 2020). Course performance during the first year of college is associated with persistence within STEM majors (Seymour et al., 2019). Providing in-course information about how to learn and succeed in college may ease the transition for students in introductory courses and improve student learning outcomes.

In this perspectives piece, we outline the importance of addressing common student questions about how to succeed in introductory STEM courses, which are often taken by first-year students. By dedicating time to address common student questions, instructors can help students who are less prepared to navigate independent learning in college courses. Indeed, the use of learning and study skills is correlated with student academic performance (Griffin et al., 2012) and in-course time dedicated to teaching learning strategies has been shown to impact student success (Cook et al., 2013).

Gathering information about what questions students have, processing that information quickly, and developing resources for students may be challenging in introductory STEM courses with hundreds of students. To help with this process, we report common questions asked by undergraduate STEM students from two research intensive universities during the Fall 2019 semester. We surveyed students in 23 introductory STEM courses spanning biology, chemistry, computer science, economics, engineering, environmental science, forestry, math, physics, and statistics. We analyzed responses from 2,112 students during the first week of the semester and 1,504 students mid-way through the semester (**Supplementary Table S1**).

Additionally, we provide advice from discussion groups of instructors about students' instructional transition from high school to college STEM courses. We found that student questions about how to succeed were similar across STEM disciplines, and by including perspectives from faculty in several departments we aim to help instructors take a collaborative approach in improving student experiences. The suggestions from faculty are based on advice these instructors give their students in response to similar questions and are grounded in faculty experiences as well as evidence-based recommendations from the STEM education literature. The detailed common student questions, possible answers, and relevant literature can help instructors reflect on student questions and address them as early as possible–even on the first day of class.

2 WHAT ARE COMMON STUDENT QUESTIONS?

We asked students to respond to an open-ended question: "If you were given the opportunity, what questions would you ask your high school teachers and college instructors about how to succeed in your college [course name] course?" We identified common themes through inductive coding (Saldaña, 2016), and coded all student responses to our open-ended questions.

Our coding revealed 12 categories of questions that students asked during both the first week and mid-semester (**Figure 1**, **Supplementary Table S2**). Overall, the top three categories represented 70% of student questions during the first week of the semester and included questions regarding *how to study and learn*, *how to maximize out-of-course time*, and *how to maximize in-course time* (e.g., note taking and minimizing distractions) (**Figure 1**). Students asked fewer questions midway through the semester, with fewer questions related to time management in particular (**Figure 1**). However, questions regarding *how to study and learn* showed no change in frequency (**Figure 1**). Of note, we did not exclude student responses from our analyses if they only replied to the first-week or mid-semester surveys, and consequently the patterns in student questions described here reflect broader patterns in student questions and are not focused on changes of individual students' questions over time.

The most common category accounted for ~50% of questions asked during either survey and consisted of questions related to *how to study and learn* (**Figure 1**). Students asked a range of questions in this category, including process-related (*how* to study and/or learn) and content-related (*what* to study - either concepts or course material) questions. The continued prevalence of questions related to studying and learning may reflect that the development of learning strategies is a continuous process throughout higher education (Christie et al., 2016) and indicates that students may be particularly receptive to hearing instructor recommendations for studying.

The next most common categories during the first week included questions related to *maximizing out-of-course time* (16% of student questions) and *maximizing in-course time* (6.8% of student questions). Each of these categories was significantly more common during the beginning of the semester than midway through the semester (**Figure 1**). Questions regarding time management outside of class may be more pressing for students during the beginning of the semester as students are evaluating how each course will fit into their weekly schedules. Additionally, questions related to *maximizing in-course time* were more prevalent during the beginning of the semester (**Figure 1**), as students are setting their habits and expectations for the in-class portions of a course.

Several categories were less common, with each accounting for <5% of responses (**Figure 1**). These categories include *how to get to know instructors or get help*, *course expectations*, *connecting the course to the real world or careers*, *differences between high school*

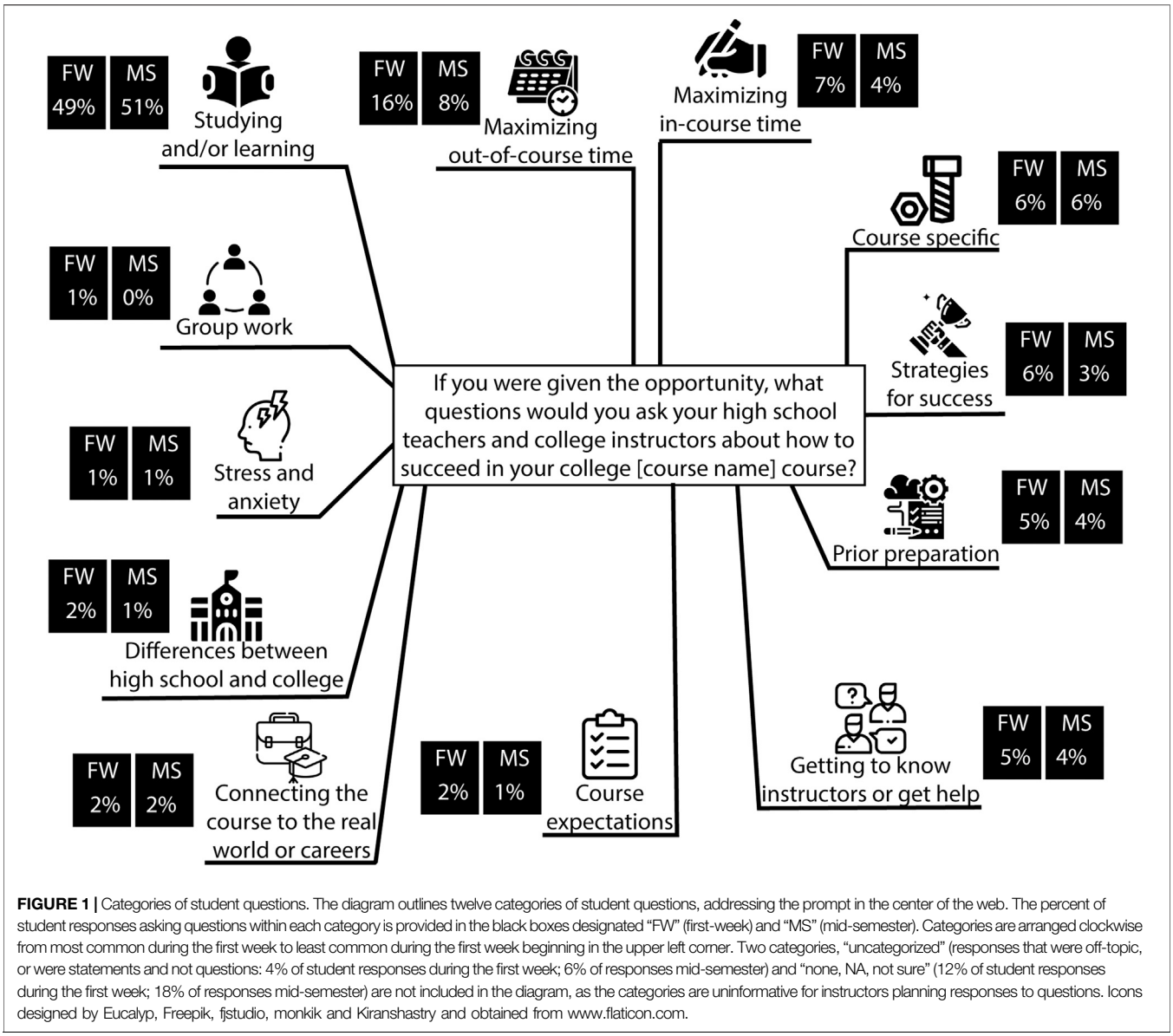

FIGURE 1 | Categories of student questions. The diagram outlines twelve categories of student questions, addressing the prompt in the center of the web. The percent of student responses asking questions within each category is provided in the black boxes designated "FW" (first-week) and "MS" (mid-semester). Categories are arranged clockwise from most common during the first week to least common during the first week beginning in the upper left corner. Two categories, "uncategorized" (responses that were off-topic, or were statements and not questions: 4% of student responses during the first week; 6% of responses mid-semester) and "none, NA, not sure" (12% of student responses during the first week; 18% of responses mid-semester) are not included in the diagram, as the categories are uninformative for instructors planning responses to questions. Icons designed by Eucalyp, Freepik, fjstudio, monkik and Kiranshastry and obtained from www.flaticon.com.

and college, *stress and anxiety*, and *group work*. Compared to the immediately applicable questions of what strategies to use for studying and learning as well as how to manage in- and out-of-course time, other question categories may have been less of a priority for students. We note that students at other institutions may have somewhat different questions, but the questions identified here represent common questions that would be expected in a variety of institutional settings.

3 HOW CAN INSTRUCTORS ADDRESS THESE STUDENT QUESTIONS IN CLASS?

To address the most common student questions, 17 instructors of introductory STEM courses met in discussion groups to strategize about how they would respond to students with questions regarding *how to study and learn, how to maximize out-of-course time*, and *how to maximize in-course time*. The instructors were members of Faculty Learning Communities (FLCs) (Cox, 2004) at two different universities. These FLCs were focused on the transition from high school to college, and faculty members met monthly and discussed national trends in STEM education, aggregate data from three participating research-intensive universities, and course-specific data collected from their own courses.

In the following sections, we have included instructor responses from all discussion groups for the top three categories of questions (**Figure 1**). In order to help introductory-level STEM course instructors anticipate student questions so that they may offer thoughtful evidence-based responses, below we include illustrative instructor responses as well as relevant literature sources.

TABLE 1 | Representative student questions and corresponding advice from faculty.

Category	Student questions	Faculty advice
Studying and learning	How do I study?	"After trying out all of the resources in class, find the resource that helps you learn the best. Persevere. Metacognitive skills will help you with these tasks."
	How do I check if I understand the material?	"Learn the material so that you can teach the material. Explain concepts to a friend/ classmate - you figure out what you do and do not know when you try explaining that information verbally to others."
	How do I check if I do not understand the material?	"Questions to ask yourself: 'Do I know how to start a problem? How do I know it is a certain type of problem? Am I finishing my assignments during problem-solving sections in time?'"
	How do I know what to study?	"Look for common themes: If it is a learning objective, in the book, in the homework it is likely to show up on the exam. Pay attention to learning objectives, they can be used as a study guide."
	How often do I study?	"To effectively study for the course, try to study everyday for a smaller chunk of time rather than studying for long hours in a single day. It is not enough to go to lecture and solve problems the weekend before the test, you need to be problem solving every day."
	How do I study in groups?	"Prior to working together, make your own personal 'study guide' and then get together and compare them with other students. During a session, teach each other the material in a group. Present big concepts, practice the worksheets/handouts/problem sets given out during class. Make sure you don't give each other the answers, but aid and help one another to get to the answers together."
	What do I ask instructors?	"If you keep missing a certain question, come in and get help. If you miss any questions on posted practice exams, come in and get help. Do not be afraid to ask questions – even if your first question is that I am not sure what to ask."
Maximizing out-of-course time	How many hours per week should I study?	"On average 2–3 h of external work for every 1 instructional hour or credit. Here is an example: 30 min of review and preparation for lecture before class, 2–3 h for every homework assignment or for worksheets, and 2 h per week for reading."
	How do I set up a weekly rhythm and plan for the academic year?	"Get a planner and PLAN AHEAD. Plan not just the submission dates and class times but also the study times - schedule all the time you will spend in the course and also on other things."
		"Balance out the work - the pace can change and sometimes material gets harder. Keep some buffer time to expand into it as needed."
		"Try to make progress daily, to keep current with ideas and assignments. Use weekends to make progress on big goals, like projects or studying for assessments."
	What should I do on a day-by-day basis?	"After every lecture, spend time reviewing the material (short-term memory is strong within 24 h)."
		"Look at the upcoming topic to brush up on skills you may need to know in advance to understand the topic, pay attention during the topic, ask questions and then work on the concepts afterward to clarify what you missed."
	Do you have any general time management advice?	"Establish routines. Plan to study during the times of day that you are most alert. Make sure to get enough sleep."
		"Treat your study time like a job. It can be easy to get distracted in a new university environment. All those instances of saying "I will just skip it this one time" can add up. If you set and stick to your schedule, you will accomplish more. Furthermore, if you finish early, your free time will feel more liberating!"
Maximizing in-course time	How should I take notes?	"Synthesize notes in your own words. If slides are provided to students, focus on annotating additional topics emphasized verbally. For discussion-based courses, write down summaries of discussions and the main points that are made."
	How can I minimize distractions in class?	"Putting your phone away, letting people know that having your phone stowed away or setting it to do not disturb so that it is not tempting as a distraction, don't read text messages."
	How do I come to class prepared?	"For courses that post notes ahead of time, the intent is that you would print these out and take notes on that so you're not trying to scramble and write down the already prepared diagram."
	How do I stay engaged or refocus if I get off track during class?	"Sit toward the front of the class."
		"Take care of yourself: Bring water and a snack to class. Stay well-rested."
		"If you find yourself getting unfocused on the activity at hand, it always helps to start writing/ journaling what is happening in the class - it brings the focus back and helps you refer to it later."

How Should I Study and Learn?

Our analysis suggests that students have questions about effective strategies, how to use them, and how to identify key concepts in the material. We summarized common ideas included under the "*how to study and learn*" code and corresponding instructor strategies for guiding students to learn effective studying and learning techniques (**Table 1**). Additionally, we share resources and literature to scaffold the process of learning for students in STEM classrooms in **Supplementary Table S3**. For example, one faculty author shares a manuscript with students that includes

study techniques and rationale for how they work (Dunlosky et al., 2013). This short paper includes information about spacing out study sessions and self-testing, and discourages students from passive re-reading and underlining. Spacing involves distributing practice or study time over several short sessions as opposed to fewer longer sessions (e.g., cramming) and has been shown in a variety of settings to be an effective study strategy (Cepeda et al., 2006; Rodriguez et al., 2018). Self-testing is a strategy of testing one's own understanding through use of practice problems (Fiorella & Mayer, 2016).

Much of the advice shared by the faculty discussion groups centered around the importance of developing self-regulated learning (SRL) and metacognitive skills that involve planning, monitoring performance, and reflecting on outcomes and learning experiences (Tanner, 2012; Zimmerman, 2002). Instructors can guide students to develop these skills by dedicating in-class time to teaching learning strategies through presentations (example resources shared in **Supplementary Table S3**) and providing examples of how they envision students structuring in- and out-of-course time. Students vary in their study strategies (Lei, 2015), and instructors can provide direction for not only what but when students study (Hora and Oleson, 2017). By providing recommendations about various study strategies, study groups, or advice on when to start studying for exams, instructors can explicitly guide students to develop their self-regulated learning skills.

How Should I Manage My Out-Of-Course Time?

Time management is often cited by students as a skill they wish to develop (Verrell and McCabe, 2015) and by researchers and educators as a skill that should be explicitly taught in undergraduate settings (Shrestha et al., 2011). Productive time management behaviors are positively correlated with academic performance (George et al., 2008; Kitsantas et al., 2008; Griffin et al., 2012) and negatively correlated with academic stress (Misra and McKean, 2000). However, while students and instructors both acknowledge how critical time management is, this topic is not often covered during the first day of class (Lane et al., *in press*). The advice faculty shared with students in **Table 1** and **Supplementary Table S4** is tailored toward both building time management strategies and fostering a sense of control over their time.

Many students asked about how many hours per week to spend per course. Faculty were cautious in ascribing numerical values in their responses to students and stressed that the number of hours can depend heavily on prior preparation or on the individual student. However, setting ranges of expectations may help students plan study/work blocks in their calendars and may help students perceive a sense of control over their schedules. Increased perceptions of student control over their time is associated with higher performance and course satisfaction (Macan et al., 1990; Adams and Blair, 2019). Concrete scheduling can help students build in time for daily course work and prevent students from putting off assignments until they are due. When making explicit time recommendations for daily studying instructors may also want to be mindful of various non-academic commitments including outside employment and caretaker responsibilities, which often impact non-traditional students more heavily.

While setting aside blocks of time is a key aspect of time management, properly managing that time is also critical. The amount of time students spend studying is only correlated with course performance when students' ability to concentrate is also high (Nonis and Hudson, 2010). This correlation underscores the importance of *effective* study time. Along these lines, the instructors in our discussion groups recommended that students use study time for self-assessments and then seek help proactively. Other important facets of time management include goal setting and prioritizing (Strickland and Galimba, 2001; George et al., 2008). Faculty encourage their students to "plan early for projects" and caution that "last minute leads to more stress, time, confusion." Indeed, students often focus on short-term deadlines at the expense of continually working toward longer-term projects (Alvarez Sainz et al., 2019). Dedicating in-course time to discussing the abstract parts of time management could encourage students to implement better strategies.

How Can I Maximize My In-Course Time?

In addition to help with study skills and time management outside of class, students in our study asked several questions about how to *maximize in-course time*, including questions that focused on how to take notes in lecture, how to make the most of in-course activities, and how to maintain focus for the duration of lecture (**Table 1**). Class periods may be longer in college than in high school, and undergraduates often have concerns about not being able to pay attention in lecture (Meaders et al., 2020).

The majority of student questions related to maximizing time were focused on aspects of note-taking. Note-taking is commonly expected of college students, and studies have shown that it is a predictor of academic achievement (Locke, 1977; Kiewra and Benton, 1988; Peverly et al., 2003; Salame and Thompson, 2020). However, students vary in the techniques they use during note-taking (Badger, 2001; Witherby and Tauber, 2019). Studies show mixed results about the influence of typed versus handwritten notes on student learning (Bui et al., 2013; Mueller and Oppenheimer, 2014). Luo et al. (2018) found that the benefits of typed versus handwritten notes may be context dependent. Therefore, it is important for instructors to let the students know what materials (lecture notes, lecture slides, activities, questions, etc.) may or may not be provided so that students can reflect on and prepare for how they want to take notes in the class. Additionally, instructors can offer their own opinions based on their experience with the course material and explicitly let students know that the methods that work in one course may not apply to all of their courses. We have compiled resources for note-taking and other recommendations for maximizing in-course time in **Supplementary Table S5**.

4 RECOMMENDATIONS FOR ADDRESSING STUDENT QUESTIONS

Instructors can proactively address student questions during course time, in the syllabus, and/or in the course website.

Below, we provide four recommendations for how to address questions and encourage discussion with students on the first day of class or at any point in time early in the semester.

Anticipate Student Questions And Start Providing Evidence-Based Recommendations/Advice to Get the Conversation Started

Student buy-in can be encouraged through the exposure-persuasion, identification, commitment (EPIC) model (Aragón et al., 2017; Cavanagh et al., 2016). **Supplementary Tables S3–S5** provide resources and recommendations to expose students to strategies focused on studying and learning, and managing in- and out-of-course time. Sharing data demonstrating strategy effectiveness for student learning is one method of persuading and encouraging students to apply strategies to their own learning. However, we also recommend that you follow the identification and commitment aspects of the EPIC model and reiterate to students that while you are providing options of strategies that they also need to identify from these evidence-based options those that work best for them. Metacognitive check-ins (Tanner, 2012) throughout the term may allow students to revisit the strategies they have tried, and to commit or recommit to productive learning strategies.

Invite Students To Come To You With Further Questions. Provide Anonymous And Non-Anonymous Opportunities For Students To Ask Questions

Anonymous options: Use note cards in smaller courses or anonymous polling from clicker-type technology or online surveys in larger courses. Anonymized questions and answers can be posted to an online discussion board for the whole class.

Non-anonymous options: Set aside time in office hours for non-content questions. During the first day of class, define office hours for students who are unfamiliar with their purpose (Smith et al., 2017). Office hours can be re-framed as "student hours" (Harnish and Bridges, 2011) or "help hours" to encourage student attendance. Furthermore, informing students that attending office hours is correlated with higher grades may incentivize attendance (Guerrero and Rod, 2013).

Virtual learning options: Incorporate digital "backchannels" (such as Mentimeter or Padlet) where students can post questions, vote on questions they would like answered, and additionally provide feedback about class pacing or other issues (Baron et al., 2016; Neustifter et al., 2016).

Inform Students That You Will Be Addressing Questions In Ways That Reach All Students

This approach lets students know that not only do you want to hear their questions but that you will respond to them and ensure that all students have access to your responses. Sharing responses may normalize the process of asking questions and may signal your investment in student success by demonstrating to students that you will take time to provide thoughtful responses. Instructors' caring about their students has been linked to increased student motivation (Chittum et al., 2019), and brief interventions during the first day can impact student perceptions of their instructors as well as student motivation (McGinley and Jones, 2014). Later in the term, course-specific questions can be addressed during the first few minutes of class or as a "brain break" during longer class periods).

Share Tips From Previous Students In The Course, Either Indirectly Or Directly From Students Themselves

One option is to invite previous students to visit during the first day or ask undergraduate teaching or learning assistants to share advice if they are graduates of the course. Advice from previous students who have successfully completed a course may carry more weight with current students and may provide additional insights into advice that could be incorporated into future course offerings (DeLine and Finck, 2008).

5 DISCUSSION

In this essay, we have detailed common introductory STEM student questions, evidence-based faculty responses to those questions, and resources for instructors who wish to address student questions in their own classrooms. Providing guidance related to *studying and learning*, *maximizing in-* and *out-of-course time* and sharing general strategies for success within introductory gateway courses may ease transitions between high school and college. Here we have highlighted the perspective of STEM instructors and related literature. We predict that these recommendations are applicable to non-STEM courses and encourage work in additional disciplines to determine if there is support for their broad usage.

Students may benefit during the first day of class from hearing advice from their instructors. While time during the first day of class is limited, instructors can provide a few specific tips and let students know that additional guidance will be shared in subsequent class periods or in discussion sections. These discussions can be dynamic and take place in the form of Q&A on an online discussion board or within small groups during the first discussion section of the semester. The syllabus is an additional space where instructors can provide advice and links to further resources.

In our student population, we saw an increase in questions regarding studying and learning by the mid-semester. Thus, students would likely be receptive to and appreciate a reminder of study strategies mid-way through the semester. Instructors could devote time after the first exam for discussions about metacognition and effective strategies, including, for example, those outlined in Tanner (2012).

Finally, we hope that these questions serve as conversation starters between instructors and students. Addressing these questions in class takes time and effort, but it is worthwhile to

ensure that instructor responses reach all students instead of solely those who feel comfortable attending office hours or emailing instructors with non-content questions. Whatever the method of information dissemination, we expect that students will respond favorably to their faculty instructors, graduate teaching assistants, and/or undergraduate learning assistants offering such advice.

DATA AVAILABILITY STATEMENT

The de-identified data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Maine protocol 2017-05-12 and Cornell University protocol 1806008047. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

CM led the data collection, analysis, and writing with input from MKS. MKS, BC, MS, and MRS conceived the study and provided significant edits. AL and AM analyzed preliminary data. CM and EV organized group discussions for the perspectives and recommendations and also collected student survey data. TB, AB, AD, SF, BK, CK, SL, WL, AMa, AMc, JN-C, KR, MS, JS, ST, Cv, MV contributed perspectives included throughout the manuscript and in **Table 1**. All authors contributed to manuscript revisions, read, and approved the submitted version.

FUNDING

This material is based on work supported by the National Science Foundation under grants DUE-1712074, DUE-1712060, and DUE-1347814 and the Center for Teaching Innovation at Cornell University.

ACKNOWLEDGMENTS

This research was considered exempt from institutional review: University of Maine protocol 2017–05-12, and Cornell University protocol 1806008047. We thank the administrators and high school teachers who donated their time to discuss the transition between high school and college with us during our Faculty Learning Community meetings. Additionally, we thank the other members of our Faculty Learning Communities for the rich discussions we held over the academic year. We also thank the Cornell Discipline-Based Education Research Group for their feedback on this manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2021.639338/full#supplementary-material.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.