Instructor Strategies to Alleviate Stress and Anxiety among College and University STEM Students

Jeremy L. Hsu* and Gregory R. Goldsmith
Schmid College of Science and Technology, Chapman University, Orange, CA 92866

ABSTRACT

While student stress and anxiety are frequently cited as having negative effects on students' academic performance, the role that instructors can play in mitigating these challenges is often underappreciated. We provide summaries of different evidence-based strategies, ranging from changes in instructional strategies to specific classroom interventions, that instructors may employ to address and ameliorate student stress and anxiety. While we focus on students in science, technology, engineering, and mathematics, the strategies we delineate may be more broadly applicable. We begin by highlighting ways in which instructors can learn about and prepare to act to alleviate stress and anxiety. We then discuss how to better connect with students and build an inclusive, equitable, and empowering classroom environment. When coupled with strategies to change student evaluation and assessment, these approaches may collectively reduce student stress and anxiety, as well as improve student performance. We then discuss the roles that instructors may play in empowering students with skills that improve their time management, studying, and approach toward learning, with an eye toward ensuring their success across all their academic endeavors. We conclude by noting areas in which further research is needed to determine best practices for alleviating student stress and anxiety.

INTRODUCTION

Several recent measures have indicated increases in mental health challenges in U.S. college students (Eisenberg *et al.*, 2013; Beiter *et al.*, 2015; Lipson *et al.*, 2018). In particular, a nationwide survey of undergraduate students in the United States identified stress (40% of all students) and anxiety (29% of all respondents) as the two most common impediments to academic performance (American College Health Association [ACHA], 2019). Stress and anxiety are complex concepts, and their denotation has been the subject of considerable debate (Lazarus and Folkman, 1984). Stress can be described as an individual's perception that a situation exceeds their ability to cope and endangers their well-being, while anxiety is described as the ambiguous feelings that arise from unresolved stress (sensu Lazarus and Folkman, 1984; as described in Bamber and Kraenzle Schneider, 2016). It is important to note that studies in educational research do not always provide formal definitions for stress and anxiety, nor do they necessarily even distinguish between the two.

While stress and anxiety may differ, it is clear that both are major challenges facing college students. In fact, more than one-third of all college students report experiencing stress that impacted their academic performance within the past academic year (ACHA, 2019; Morey and Taylor, 2019), and students with high stress are more at risk of attrition or leaving college (Muller *et al.*, 2017). In addition, student anxiety can also negatively influence persistence in the biology major (England *et al.*, 2017, 2019). The prevalence of these mental health challenges is a complex issue that requires engaging stakeholders from across an institution, and there are undoubtedly many factors that can contribute to student anxiety and stress beyond academics. Here, we focus specifically on the role that instructors can play in supporting students and

mitigating their stress and anxiety, providing a review of evidence-based practices that instructors can use to lower student stress and alleviate anxiety.

The role of higher education instructors in mitigating student stress, anxiety, and mental health challenges is underexplored (Di Placito-De Rango, 2018). Although there have been a number of studies, reviews, and books that examine factors that may contribute to student anxiety and stress, as well as potential interventions that may help reduce anxiety in students (Hattie *et al.*, 1996; von der Embse *et al.*, 2013; Regehr *et al.*, 2013; Ribeiro *et al.*, 2018; Yusufov *et al.*, 2019), many of those works do not specifically focus on college students or do not focus on the instructor. Instead, these reviews tend to emphasize broader programmatic steps that can be adopted by an institution that may not be directly applicable for an instructor. In contrast, our objective is to provide evidence-based strategies that can be implemented by new and experienced instructors to reduce their students' stress and anxiety and ultimately improve students' academic performance and quality of life. We provide these strategies in the context of our own experience as instructors in the life sciences and therefore in the context of science, technology, engineering, and mathematics (STEM) literature and disciplines; however, we expect that many of the approaches summarized here should be applicable to other academic disciplines. To organize our review, we focus these strategies into five main categories that span the arc of interacting with a student from the start to the end of a course and beyond:

1. Learning and preparing to act
2. Connecting with students
3. Building an empowering atmosphere in the classroom
4. Reducing testing anxiety
5. Promoting effective academic skills

In addition, we provide a summary of these strategies (Table 1) and a short list of recommended literature for instructors to read to learn more about these strategies (Box 1). In all these strategies, we recognize that instructors may feel unqualified or uncomfortable addressing such challenges and may be wary of exacerbating mental health concerns (White and LaBelle, 2019). We emphasize that our advice here does not suggest that instructors take the role of mental health professionals; clear boundaries must be established when interacting with students regarding issues of mental health more generally. However, we hope that these evidence-based strategies can help instructors become informed and improve their ability to act proactively and respond to such challenges.

LEARNING AND PREPARING TO ACT
In this first category, we describe the steps that instructors can take to familiarize themselves with the many ways that stress and anxiety can manifest in students, as well as the campus resources for helping students in crisis. Instructors, in part because of their frequent contact with students, can play a critical role as "first-line responders" in recognizing challenges, rendering support, and redirecting students to other resources (Di Placito-De Rango, 2018).

Recognizing Underlying Mental Health Challenges
Academic performance and the pressure to succeed (or, conversely, the fear of failing) are known drivers of stress and

anxiety in college students (Beiter *et al.*, 2015). Both stress and anxiety have been closely associated with depression and other mental health challenges as well as physical illness in college students (Kumaraswamy, 2013; Mahmoud *et al.*, 2012; Rawson *et al.*, 1994). These mental health challenges can manifest in many different forms, including depression and thoughts of, or attempts at, suicide (Garlow *et al.*, 2008).

Although instructors cannot (and should not) serve as health professionals, instructors can learn about common mental health challenges relating to stress and anxiety. Instructors who familiarize themselves with and are aware of mental health challenges can better direct students to the proper resources and likewise will have greater insight into how to approach these conversations with students if and when they arise.

Many universities offer seminars or short trainings led by the campus health resources that are explicitly intended for instructors. While there is no replacement for seeking professional help, and some students may need more intensive mental health supports, these workshops provide instructors with basic training on how to provide support and identify students in need. Trainings can enable instructors to be more familiar with the range of potential mental health challenges students may be facing, guide instructors through how to hold conversations supporting students and referring them to mental health resources when needed, and provide a range of possible resources for instructors to be aware of. Trainings often include role-playing practice sessions to allow instructors to be more comfortable in conversations in which students approach an instructor and appear anxious, depressed, or suicidal. Trainings may also discuss the role of faculty as mandated reporters in connecting students in danger with additional resources. For those who wish to educate themselves further or whose campuses lack resources, the American College Health Association (www.acha.org) and the Jed Foundation (jedfoundation.org) are two organizations that provide accessible starting points. The more instructors become familiar with these underlying mental health challenges, the better prepared they are to appropriately respond and refer students to the proper resources when faced with a student in need.

Know and Promote Campus Resources
Instructors can familiarize themselves with various campus resources, such as where to refer students if they need mental health assistance, as well as the campus public safety office and emergency medical services. However, many universities also have an explicit protocol for contacting the office of student affairs (or equivalent) if an instructor is concerned about a student who is experiencing an emergency and/or needs more immediate mental health assistance. Having a list of phone numbers and addresses easily accessible can be helpful so that instructors can connect a student to the appropriate resources or contact such resources directly when appropriate if there is a student in need (e.g., if a student appears to be struggling, has abruptly changed their behavior, or has communicated major stressors, like a death in the family, with the instructor). Similarly, instructors should encourage students to use the resources available on campus. Common resources (albeit with different titles, depending on the institution) include counseling services, academic tutoring centers, and disability services. College students consistently report a poor understanding of what

TABLE 1. A summary of the strategies that can be employed by instructors to reduce student stress and anxiety

Category	Strategy	Summary of strategy
Learning and preparing to act	Recognize underlying mental health challenges. Know and promote campus resources.	Become familiar with underlying mental health challenges, and know how and when to refer students to campus resources if needed.
Connecting with students	Use student names. Empathize with students and provide opportunities for interpersonal connection.	Take steps to learn student names, such as using name tents, and connect with students to increase instructor immediacy.
	Use humor.	Use appropriate humor to promote a positive classroom atmosphere.
Building an empowering atmosphere in the classroom	Shape active-learning strategies to minimize anxiety. Be deliberate when forming student groups.	Be aware of some active-learning strategies (e.g., cold-calling) that can increase stress and take steps to decrease anxiety when using active-learning techniques, such as structuring groups carefully or allowing students to form their own groups.
	Create an inclusive and equitable classroom. Choose words carefully.	Be explicit about promoting a classroom environment where all students are included and treated equally; be aware of and avoid microaggressions or language that introduces a stereotype threat.
Reducing testing anxiety	Reduce or modify high-stakes testing.	Build in alternate means of assessment to reduce high-stakes tests that lead to high anxiety, or modify the structure of exams to lower stress.
	Perform classroom interventions.	Use specific interventions, like having students write about their anxiety, in order to reduce their stress and improve their performance.
Promoting effective academic skills	Instill effective study habits and time management skills. Use metacognition. Promote a growth mindset.	Promote strong learning strategies and a growth mindset so students know they can improve.

mental health resources are available to them, and instructors can play a role in increasing awareness (Zivin *et al.*, 2009; Dobmeier *et al.*, 2013). Even if they are aware of the resources, students may be hesitant to reach out due to a perceived stigma or other barrier (Eisenberg *et al.*, 2009; Wu *et al.*, 2017). Engaging students in conversation does not guarantee that they will seek additional help (Mitchell *et al.*, 2012). Nevertheless, discussing these resources and encouraging students to use these support systems can ensure that more students experiencing stress, anxiety, or other mental health challenges are paired with the proper resources.

A range of other campus resources are often available to students to help alleviate stress and anxiety stemming from academic pressures. Many universities offer courses or workshops on academic skills, study strategies, and time management; different variants of these programs have been shown to promote student performance and retention and lower stress, as discussed later in the section on effective academic skills (Macan *et al.*, 1990; Kimbark *et al.*, 2017). Some universities also offer peer tutors who can assist with either course content or academic skills. Instructors can familiarize themselves with these resources, ensure that students in their classes are aware of these resources, and refer students to these support systems when needed.

CONNECTING WITH STUDENTS
In this category, we discuss several strategies that instructors can use to promote connections with students. Establishing

> **BOX 1. An Annotated List of Additional Reading**
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> - Cooper and Brownell (2020): In this book chapter, Cooper and Brownell summarize the literature on how active learning impacts anxiety in the college science classroom and provide more information on how to best employ active-learning techniques while minimizing stress.
> - Tanner (2013): In this synthesis paper, Tanner provides a summary of strategies instructors can take to improve engagement and equity in the classroom. While this article was not written in the context of reducing stress and anxiety, it provides direct and useful strategies for building an inclusive classroom, and several of the strategies outlined (learn or have access to students' names, do not judge responses, use praise with caution, etc.) may increase instructor immediacy. Promoting an empowering classroom atmosphere and increasing instructor immediacy may lower stress and anxiety.
> - Hodges (2018): In this article, Hodges discusses different types of group work in the classroom, group formation, how students learn in groups, and why some groups fail. This article provides insight into how instructors can most effectively manage group work, thus lowering stress.
> - Regehr *et al.* (2013): In this article, Regehr and coauthors provide a review and meta-analysis of interventions to lower stress in college students. While most of the interventions are broader campus-level interventions that are not realistically implemented in a classroom by an instructor, the article provides great insight into what techniques are most effective at lowering stress in college students.

these connections increases instructor immediacy, the perception of relational closeness and connection between the student and the instructor (LeFebvre and Allen, 2014). This can make students more comfortable in class and more willing to engage with the instructor both inside and outside class (Cooper *et al.*, 2017). Unsurprisingly, it has been demonstrated in both non-STEM and STEM classes that student anxiety decreases as instructor immediacy increases (Williams, 2010; Mazer *et al.*, 2014; Kelly *et al.*, 2015). Thus, while there are only a limited number of studies directly examining the impact of the strategies we describe here on student stress or anxiety, each strategy has been shown to promote instructor immediacy and thus may help mitigate student anxiety.

Use Student Names

One of the simplest steps that instructors can take to connect with students and increase instructor immediacy may be to learn and use their preferred names and pronouns. While learning names may be more challenging for instructors teaching large classes, there are several strategies that instructors can use to learn student names more effectively. For instance, many institutions offer photo rosters to help instructors recognize and learn student names. Similarly, an increasing number of institutions now allow students to record their name out loud, helping instructors pronounce names more easily. Cooper *et al.* (2017) find that using name tents—pieces of paper on which students write and display their preferred names—helped dramatically increase the perception that the instructor knew student names in a high-enrollment biology class, which led students to report positive impacts on their attitudes, behaviors, and perceptions of the course. For instance, many students felt more valued, more invested in the course, and more comfortable communicating with the instructor and reaching out for help; they also stated that the use of names made them feel like the instructor cared about them and helped establish better student–instructor relationships (Cooper *et al.*, 2017). These are all attributes that promote increased instructor immediacy and are thus associated with reduced anxiety (Jaasma and Koper, 1999; Baker, 2004; Creasey *et al.*, 2009). Notably, the results reported by Cooper *et al.* (2017) are despite the fact that the instructor did not actually know the names of all students. Instructors can also ask students to write preferred pronouns on their name tents if the students are comfortable doing so; this optional use of pronouns provides an opportunity for lesbian, gay, bisexual, transgender, queer, intersexual, or asexual (LGBTQIA) students to convey their preferred pronouns for both the instructor and their classmates if they so wish, thus creating a more inclusive environment and potentially lowering their stress (Cooper *et al.*, 2020). Students have also reported that instructors learned their names through interactions during class, immediately before and after class, during office hours, and in other conversations outside class time (Cooper *et al.*, 2017). However, instructors should be cognizant that the use of names in some contexts may increase anxiety; students in K–12 classrooms have reported anxiety if instructors mispronounce their names (Kohli and Solórzano, 2012), and the use of names for random cold-calling can also increase anxiety (Cooper *et al.*, 2018a; Waugh and Andrews, 2020). Beyond using name tents, we have found that arriving a few minutes before the start of class to allow for time to set up, as well as to check in and greet students, allows us to more effectively connect with students and learn their names.

Empathize with Students and Provide Opportunities for Interpersonal Connection

In addition to learning and using student names, instructors should work to empathize with students and provide opportunities for interpersonal connection; these attributes have been shown to increase the perception of students that instructors care about them (Teven, 2001), which has been shown to be associated with increased instructor immediacy (Schutt *et al.*, 2009). In addition to the informal conversations that occur in the few minutes before and after each class, sharing personal stories can also enliven the classroom and help counter student perceptions about the course, topic, and/or instructor. The use of "noncontent instructor talk" in class—defined as any instructor language that does not directly convey the course concepts—has been documented as a way to build the relationship between the instructor and student, establish classroom culture, and increase instructor immediacy (Seidel *et al.*, 2015). Our own experiences suggest that noncontent instructor talk outside class (e.g., during office hours or individual meetings with students) may also provide the same benefits. By sharing certain personal experiences, we enable interpersonal connection and may promote a growth mindset by illustrating our own growth when we were students (as discussed later). For instance, when faced with students who struggle on a quiz or exam, we often bring up an example of an undergraduate exam gone wrong from our own experiences as students. We then discuss how we changed our study habits and how we improved following that experience. Sharing these stories encourages students and likely promotes greater instructor immediacy that may lower anxiety by showing that it is possible to recover from a poor test performance.

Use Humor

The use of appropriate humor in class can also lessen anxiety in the classroom (Wanzer and Frymier, 1999; Cooper *et al.*, 2018b). While there are many categories of inappropriate humor (such as ones that marginalize or disparage groups of students) that can damage student–instructor relationships, the use of appropriate humor can be used to strengthen the student–instructor relationship and establish a more positive classroom climate (Bekelja Wanzer *et al.*, 2006; Cooper *et al.*, 2020). In addition, the use of humor can also increase student perceptions of learning as well as their motivation and willingness to engage in class (Wanzer and Frymier, 1999; Neumann *et al.*, 2009; Banas *et al.*, 2011). Embedding humor into exams and other assessments has also been shown to lead to lower stress and increased perception of exam performance by students (Berk, 1996, 2010).

BUILDING AN EMPOWERING ATMOSPHERE IN THE CLASSROOM

While connecting with students is important, it is equally critical to build a classroom atmosphere that empowers all students to feel comfortable learning, which may correlate with reduced student anxiety in the biology classroom in some contexts (Cooper and Brownell, 2016). There are several strategies that instructors can take to promote such a dynamic.

Shape Active-Learning Strategies to Minimize Anxiety

The benefits of active-learning strategies have been well documented, including increased learning for students, a decrease in the achievement gap for identities historically underrepresented in the sciences, and improved attitudes and perceptions toward science (Armbruster *et al.*, 2009; Haak *et al.*, 2011; Freeman *et al.*, 2014; Theobald *et al.*, 2020). However, recent research has indicated that many active-learning techniques can also increase student anxiety or the perceptions of student anxiety (England *et al.*, 2017; Cooper *et al.*, 2018a; Cooper and Brownell, 2020; Downing *et al.*, 2020) and that students employ both adaptive and maladaptive strategies to cope with this anxiety (Brigati *et al.*, 2020). Ultimately, students with high anxiety may even learn less in an active-learning classroom (Cohen *et al.*, 2019). Some techniques, such as cold-calling—asking a student to share a response with the class without the student volunteering—have been identified as producing particularly high anxiety in students (England *et al.*, 2017; Cooper and Brownell, 2020; Waugh and Andrews, 2020). Even modifying common techniques, such as cold-calling, to reduce apprehension may still lead to increased student anxiety as compared with not using such techniques (Broeckelman-Post *et al.*, 2016). In addition, different demographics of students (e.g., underrepresented students and students who speak English as a second language) may feel disproportionate amounts of stress and anxiety in an active-learning classroom (Mak, 2011; Freeman *et al.*, 2014; Cooper and Brownell, 2016). Similarly, such active learning has the potential to disproportionately impact underrepresented students; for instance, Cooper and Brownell (2016) find that students in biology classes who are LGBTQIA report that in-class group work, particularly if they are not allowed to choose their own groups, can increase their stress and anxiety, given that they are faced with the challenge of potentially working with students who are not accepting of their identities.

While the diversity of active-learning techniques makes it challenging to generalize about active learning and classroom anxiety, there are a few active-learning techniques that may be less stressful than others. For instance, Cooper *et al.* (2018a) find that some types of active-learning strategies, such as clicker questions and group work, have the potential to help lower anxiety levels for some students. Ultimately, few studies to date have investigated the impact of active-learning interventions on reducing anxiety. While none of these studies suggest that instructors move away from active-learning techniques, given their benefits to student learning and retention, instructors can take steps to minimize the stress and anxiety often associated with these techniques by explaining the rationale behind their pedagogical techniques, allowing students to form their own groups, and providing students the time to think individually and share with partners before being asked to share with the class (England *et al.*, 2017; Cooper *et al.*, 2018a). These steps can also increase trust in the instructor in an active-learning class, which has been shown to lead to increased student performance (Cavanagh *et al.*, 2018), and would likely promote a more comfortable classroom atmosphere. While the term "active learning" encompasses a wide range of possible techniques in biology education and STEM education more generally (Driessen *et al.*, 2020), instructors can use evidence-based guides and frameworks to aid their implementation of active learning and their response to student feedback (e.g., Allen and Tanner, 2005; Seidel and Tanner, 2013; Stains and Vickrey, 2017). Our own experiences align, with several students expressing to us in past courses that while they were initially resistant to some of the active-learning techniques we implemented in class, hearing the pedagogical justification and seeing the results made them more accepting of these techniques.

Be Deliberate when Forming Student Groups

There is a growing body of empirical studies examining student group work and its impact on learning and attitudes (Jensen and Lawson, 2011; Chang and Brickman, 2018; Hodges, 2018).

While the formation of groups is highly context dependent (e.g., size of class, lower division or upper division, duration of group work), several studies have found that student learning and perceptions of learning increase, and anxiety decreases, when students are familiar with and comfortable sharing with their group mates (Theobald *et al.*, 2017; Downing *et al.*, 2020). Student anxiety is often driven by the fear of negative evaluation by peers and instructors (Watson and Friend, 1969; Weeks *et al.*, 2005; Downing *et al.*, 2020), and thus instructors can take steps to promote student familiarity and comfort with their groups. These include activities that provide an opportunity for students in groups to get to know one another and to establish group norms (Chapman and Auken, 2001). Students have also reported more positive group experiences with increased structure in group work (Theobald *et al.*, 2017; Chang and Brickman, 2018). Thus, instructors may be able to lower student stress by assigning roles for students in groups; providing clear expectations with specific goals, objectives, and deadlines; and structuring activities so that students bring different pieces of expertise to the project.

Instructors may also allow students to choose their own groups, depending on the course context. Doing so can lessen stress and anxiety, particularly among students who may not wish to disclose parts of their identities (Cooper and Brownell, 2016). Allowing students to choose their own groups can also lessen fear of negative evaluation by their peers and thus decrease stress (Cooper and Brownell, 2020; Downing *et al.*, 2020). However, instructors should be aware that doing so may increase stress and anxiety for some students, such as those who do not readily find a group (Rosser, 1998; Strauss *et al.*, 2011; Henning *et al.*, 2019; Juvonen *et al.*, 2019).

Our own experience with group work affirms the complicated nature of forming student groups. Our best outcomes often come from forming groups around an affinity for a theme or topic that will be pursued for the project (e.g., a group of students all interested in doing a final project focused on genetics). We have also observed that allowing groups to remain consistent for a longer period of time (e.g., an entire unit or a semester-long project) can allow for group norms and foster a sense of community in the classroom that also extends outside the classroom, with students forming social networks with their groups and also relying on their partners for studying. Instructors may wish to refer to the evidence-based guide to group work from Wilson *et al.* (2018), which provides further context on the formation of groups.

Create an Inclusive and Equitable Classroom

Because student anxiety is often driven by fear of negative evaluation, fostering an inclusive and equitable classroom

atmosphere where students are comfortable with being wrong can decrease student anxiety and stress and promote a more inclusive classroom (Cooper and Brownell, 2020; Downing *et al.*, 2020). Downing *et al.* (2020) find that student fear of negative evaluation may be reduced by allowing students to work in groups with other students whom they know (see previous section), providing a chance for students to talk to their classmate before sharing with the class (referred to as "warm calling"), and framing errors as part of the learning process. Positive error framing can reduce stress and lead to both improved metacognition and learning for the student (Steele-Johnson and Kalinoski, 2014; Downing *et al.*, 2020). If a student does perform poorly, Henry *et al.* (2019) outline a theoretical framework for how students can appropriately cope (e.g., problem solving, support seeking, and cognitive restructuring); by encouraging student ownership over their own learning and providing support, instructors may lessen the impact of the failure, promote future improvement, and ultimately alleviate stress.

Choose Words Carefully
Instructors can be cognizant of their choice of language and avoid microaggressions that may either consciously or subconsciously lead to some students not feeling welcome or included (Harrison and Tanner, 2018). Microaggressions—directly or indirectly speaking negatively about student identities—can make students feel unwelcome and thus elevate stress and contribute to anxiety (Harrison and Tanner, 2018). In contrast, the use of "microaffirmations"—any nonobvious verbal or nonverbal cues to demonstrate kindness—can counteract the impact of microaggressions and promote student persistence (Estrada *et al.*, 2019). Such microaffirmations have been suggested to lower stress in certain populations of college students, such as first-generation students (Ellis *et al.*, 2019), perhaps by alleviating a sense of isolation that can be associated with stress and anxiety (Harrison and Tanner, 2018).

Instructors can similarly reduce stereotype threat, that is, the "risk of confirming a negative stereotype," or an association/expectation of conforming to a preconceived notion about a certain group of individuals (Steele and Aronson, 1995). Stereotype threat has been shown to increase student anxiety (Bosson *et al.*, 2004; Osborne, 2007) and negatively impact student performance and achievement (Osborne, 2001; Cadinu *et al.*, 2003). In addition to eliminating language that promotes stereotype threat, instructors can also perform specific interventions to mitigate stereotype threat. Seidel *et al.* (2015) posit that some types of noncontent instructor talk can help reduce stereotype threat. For instance, explicitly delinking the often-perceived association between exams and intelligence can decrease the impact of stereotype threat (Croizet and Claire, 1998; Spencer *et al.*, 1999; Binning *et al.*, 2020). Similarly, Johns *et al.* (2005) find that explicitly teaching about stereotype threat can help reduce the negative impacts of such stereotype threat; in their study, an intervention in which the instructor explained the idea of stereotype threat to women before those women took a math exam led to lower anxiety and higher performance.

In contrast to the negative impacts of stereotype threat, interventions that promote values affirmation—the process of positively reinforcing values important to students—can

counter the effects of stereotype threat (Jordt *et al.*, 2017). Values affirmation may also lower stress levels (Creswell *et al.*, 2005), though some specific values affirmation interventions may not alleviate levels of anxiety (Czech *et al.*, 2011; Peters *et al.*, 2017). Despite this, values affirmation has been found to increase performance and reduce achievement gaps (Cohen *et al.*, 2006; Miyake *et al.*, 2010; Freeman *et al.*, 2014; Peters *et al.*, 2017). Even simple interventions that ask students to describe their values and how they practice and demonstrate these values in everyday life can be beneficial for students (Jordt *et al.*, 2017).

REDUCING TESTING ANXIETY
Exams and tests can often be a source of stress and anxiety for students. In this section, we first describe structural changes that instructors can make to such assessments to lower stress and anxiety and then describe interventions that can be used to lower anxiety before or during such assessments.

Reduce or Modify High-Stakes Testing
High-stakes testing has been known to cause anxiety in students across a diversity of settings (Cizek and Burg, 2006; Kruger *et al.*, 2007). In addition, there is evidence that women and underrepresented students may be disproportionately disadvantaged by such high-pressure exams (Ballen *et al.*, 2017). Test anxiety can also contribute to increased student perceptions of difficulty and lower academic performance (England *et al.*, 2019). As such, if instructors can reduce or eliminate high-stakes testing whenever possible, then this may reduce student anxiety (Putwain, 2008). For example, instructors can add smaller-stakes quizzes to reduce the proportional weight of exams as well as to create a means for formative assessment that informs both the instructor and learners. In addition, instructors can implement schemes to reward improvement over time (e.g., Bailey *et al.*, 2017) or drop the lowest quiz or exam score. This approach lowers the potential impact of each individual assessment. Finally, instructors can explore alternate means of assessments beyond high-stakes testing, such as problem sets, essays, and lab reports (Ballen *et al.*, 2017). Beyond the potential to reduce stress, using a diversity of methods for assessments (and thus lowering the weight of exams) has been shown to reduce the achievement gap of females in biology on both exams and the course as a whole (Ballen *et al.*, 2017).

In addition, multiple studies demonstrate that open-book exams, or exams wherein students can bring in a "cheat sheet" with notes, can lower student stress (Durning *et al.*, 2016; Erbe, 2007; Gharib and Phillips, 2012). However, the impacts of modifying exams to allow notes on student learning is unclear; while some studies report some improved learning gains or no impact on student learning or performance (Sato *et al.*, 2015), other studies have found negative consequences on learning, retention, and student motivation (Moore and Jensen, 2007; Durning *et al.*, 2016).

Perform Classroom Interventions
There are also several interventions that instructors can implement to help reduce student anxiety and/or increase student performance for an exam or a course. For instance, concept mapping has been found to lower student anxiety about the learning of biology, a benefit attributed to increased

metacognition, as discussed elsewhere (Okebukola and Jegede, 1989; Jegede *et al.*, 1990). In addition, asking highly anxious students to write about their testing worries immediately before an exam has repeatedly been demonstrated to help counter the expected negative impact of this anxiety on their test performance (Frattaroli *et al.*, 2011; Ramirez and Beilock, 2011; Park *et al.*, 2014). Similarly, several studies on stress reappraisal, the guiding of students to perceive stress and anxiety as beneficial given the possibility of increased focus and attention, have also been shown to both decrease anxiety and increase exam performance (Jamieson *et al.*, 2013; Jamieson *et al.*, 2016). In sum, these interventions have been shown to increase student performance for all students, including both low- and high-anxiety students (Harris *et al.*, 2019). Instructors can either implement these interventions or let students know of the relevant research if they struggle with testing anxiety. Similarly, instructors can use published interventions relating to these themes that have been successfully implemented in a variety of courses (Doherty and Wenderoth, 2017; Harris *et al.*, 2019). Finally, there are also a number of more general interventions that instructors can promote to lower stress, such as providing access to "comfort" or therapy dogs before an exam (Barker *et al.*, 2016; McDonald *et al.*, 2017; Schroder *et al.*, 2017; Trammell, 2017; Jarolmen and Patel, 2018), or encouraging students to attend mindfulness and meditation classes (Bamber and Kraenzle Schneider, 2016).

PROMOTING EFFECTIVE ACADEMIC SKILLS

The strategies that have been described thus far are implemented by an instructor to reduce student stress and anxiety. However, there are many academic skills and strategies that a student could use to lower stress and anxiety; these strategies can therefore be implemented directly by the student in any course. In this section, we describe strategies that instructors can recommend to their students to improve time management and study skills, as well as promote students' own thinking about how they learn and their mindset toward the process of learning. While we acknowledge that instructors can also recommend ways in which students can cope with (i.e., manage) stress and anxiety, our intent here is to discuss strategies that instructors can instead take to prevent student stress and anxiety.

Instill Effective Study Habits and Time Management Skills

Ineffective study habits and time management have been found to correlate with anxiety and lower student performance, and thus there have been calls for instructors to facilitate development of these skills in order to lower student anxiety (Wittmaier, 1972; Bruch, 1981; Macan *et al.*, 1990; Nonis *et al.*, 1998; Cizek and Burg, 2006). Students may not be aware of how to study effectively, and thus instructors can promote these study strategies by discussing them with their classes. These strategies include 1) explicitly discussing the use of learning objectives with students and modeling the writing of a question based on a learning objective (Osueke *et al.*, 2018); 2) suggesting that students retake past quizzes, exams, and assessments and reflect upon their performance (Walck-Shannon *et al.*, 2019); 3) teaching students how to self-evaluate their own work (Osterhage *et al.*, 2019); 4) guiding students toward self-regulated learning, wherein they set goals and monitor progress toward those goals (Sebesta and Bray Speth, 2017); 5) encouraging group studying, so students can clarify concepts with peers (Kritzinger *et al.*, 2018); and 6) promoting regular and spaced-out study time in preparation for tests (Roediger and Karpicke, 2006).

Similarly, targeted programs to promote time management in college students have lowered their stress and anxiety (Häfner *et al.*, 2014a,b; Aeon and Aguinis, 2017). The core elements of these interventions include prioritizing, goal setting, strategy development, daily planning, and the establishment of monitoring and reward structures as achieved by a series of self-reflection questions followed by a planning exercise (Häfner and Stock, 2010). Such interventions may be particularly useful for reducing procrastination and time discounting on larger or more long-term activities (Koch and Kleinmann, 2002). We regularly implement brief self-reflection exercises in the classroom, often focused on daily planning that includes the explicit incorporation of rewards that are also expected to reduce stress and anxiety (e.g., going to the gym to exercise after finishing an assignment).

Use Metacognition

Multiple studies have indicated that promoting metacognition, a process in which students think about and reflect upon their own learning, can lead to reductions in test and course anxiety (Alaiyemola *et al.*, 1990; Everson *et al.*, 1994; Matthews *et al.*, 1999; Spada *et al.*, 2006). Students generally need to be prompted to deliberately engage in metacognition, and instructor assistance may be needed to guide student thinking about studying, particularly for students earlier in their college careers (Stanton *et al.*, 2019). For instance, instructors can implement exam wrappers, a questionnaire usually provided to students after an exam that asks them to reflect on their studying, preparation, and performance on the exam (Pate *et al.*, 2019). The use of exam wrappers may lead to increased knowledge of cognition and higher performance (Gezer-Templeton *et al.*, 2017; LaCaille *et al.*, 2019; Langdon *et al.*, 2019; Edlund, 2020). Instructors may also choose to use "enhanced answer keys" with reflective metacognitive questions embedded to deliberately prompt student metacognition (Sabel *et al.*, 2017). Similarly, instructors can implement such metacognitive questions into homework or problem sets or ask students questions that promote metacognition during individual or class meetings. For instance, as instructors, we regularly prompt students to use note cards to reflect on what they did well in the past week and what they wish to improve on in the coming week as a simple method for promoting metacognition.

Promote a Growth Mindset

Language that promotes a growth mindset, or the belief that skills, personality, and intelligence can change and be improved, has been linked to greater academic achievement and improved grades (Claro *et al.*, 2016; Yeager *et al.*, 2019). This contrasts with a fixed mindset, whereby students believe that their intellectual abilities are immutable (Dweck, 2000; Claro *et al.*, 2016). Likewise, fostering a growth mindset has been shown to mitigate stress and anxiety in psychological studies (Schleider and Weisz, 2016, 2018; Schroder *et al.*, 2017). While the literature examining a growth mindset and the impact on stress in

the classroom is sparse, instructors can have a direct influence on students' perceptions of a growth mindset (Powers, 2015). Instructors can incorporate short messages promoting a growth mindset in the classroom and encourage further growth and improvement in students. We often praise students on improvement and encourage students who struggle to come talk to us, reflect on their learning, and then improve on the next assessment. In addition, course policies that reward increased learning may also promote a growth mindset, reducing anxiety while fostering and maintaining student motivation. For example, Fernandez (2020) describes promoting a growth mindset by structuring grading around mastery, while providing students a second chance at answering questions on an exam.

OPPORTUNITIES FOR FUTURE RESEARCH

While the relationships between student stress and anxiety and academic performance are relatively well established, there remain many opportunities to establish and strengthen our understanding of what practices instructors can adopt to decrease stress and anxiety. We highlight three main areas.

How Applicable Are These Strategies and Interventions for Reducing Stress and Anxiety among Different Demographics?

Students report different levels of stress and anxiety depending on gender, ethnicity, and sexual orientation (Eisenberg *et al.*, 2013; Posselt and Lipson, 2016). It is not clear that a strategy to reduce stress and anxiety studied among one student demographic will be applicable to another. Moreover, there appear to be systematic biases in the current literature. For instance, a recent analysis of biology education research found biases in study populations, with the majority of studies focusing on undergraduate students at research-intensive institutions (Lo *et al.*, 2019). Relatively few biology education studies have focused on community college and transfer students, despite those students making up nearly half of postsecondary biology students in the United States and generally comprising a more diverse population than students at research-intensive institutions (Schinske *et al.*, 2017). We found only a few studies that focused explicitly on studying stress or anxiety in these populations (Powers, 2015; Kimbark *et al.*, 2017; Downing *et al.*, 2020). Future research is needed to examine the generalizability of these strategies among different student populations and among different identities more generally.

How Applicable Are These Strategies and Interventions for Reducing Stress and Anxiety in Different Contexts?

Students also report different levels of stress and anxiety depending on STEM major (May and Casazza, 2012). It is not clear that a strategy to reduce stress and anxiety studied in one discipline will be applicable to another or that the strategy will be relevant for different concepts within a discipline. For instance, some of the strongest evidence regarding strategies that can reduce anxiety and increase performance (e.g., informing certain groups about stereotype threat, using humor to connect with students, expressive writing before taking an exam) arise from studies carried out in mathematics and statistics courses (Spencer *et al.*, 1999; Johns *et al.*, 2005; Neumann *et al.*, 2009, p. 200; Williams, 2010; Park *et al.*, 2014). Each of

these strategies could be applied in biology; however, their efficacy generally remains untested. Similarly, if effective, the strategies could also be applied to reduce math anxiety in the context of the biology classroom (e.g., Madlung, Bremer, Himelblau, and Tullis, 2011). Future research is needed to examine whether strategies applied in one context will work in another context. When combined with the need to consider how different student identities respond to a given strategy, this presents a significant challenge for the field moving forward.

What Strategies Have a Weak or Nonexistent Evidence Base?

In many cases, the strategies that we identify here currently lack evidence for direct linkages with reductions in stress and anxiety. For instance, the use of student names is predicated on the linkage between name use and instructor immediacy. There is a need for additional research that explicitly measures student stress and anxiety as a function of different classroom interventions, even if only ancillary to the primary purpose of the study. This research should strive to adopt more explicit definitions of stress and anxiety, although we recognize that the many conceptualizations of stress and anxiety make this quite challenging (Lazarus and Folkman, 1984). In addition, we identified several strategies that are likely to be related to student stress and anxiety but have no clear evidence base. For instance, many students perceive office hours negatively, with students often citing apprehension about using office hours and viewing them as a last resort (Smith *et al.*, 2017). Despite the stress and anxiety that can be created by office hours, research on best practices remains limited and presents an area for future research.

CONCLUSION

Some stress and anxiety are likely unavoidable, and students can also learn various coping mechanisms through the adoption of healthy academic (e.g., problem solving, information seeking, emotional regulation, etc.; Henry *et al.*, 2019) and self-care habits (e.g., sufficient sleep, getting exercise, identifying a supportive community of friends; Myers *et al.*, 2012). However, we have focused here on identifying evidence-based strategies that instructors can employ to try to reduce student stress and anxiety so that students can reach their full potential in the classroom. These strategies span a range of approaches, from modifying instructional techniques to empowering students with different mindsets and tools that they can use to alleviate stress. Instructors can pick and choose among these strategies depending on context, but should always think about ways to assess their efficacy. In that sense, our review also exposes the need for new studies that explicitly link instructional techniques with student stress and anxiety and that identify how those relationships vary among STEM disciplines and across diverse student demographics.

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