The Experiences of Undergraduates with Depression in Online Science Learning Environments

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ABSTRACT

Depression is one of the top mental health concerns among undergraduates and disproportionately affects students who are underrepresented in science. As such, understanding how emerging science learning environments, such as online science courses, affect students with depression is integral to creating a more inclusive scientific community. In this exploratory study, we interviewed 24 undergraduates with depression who were pursuing an online BS degree in biological sciences at a research-intensive institution. We assessed how students perceived depression affected their learning, and in turn, how online science courses affected their depression. Using a hybrid approach of deductive and inductive coding, we found that students reported depression negatively affected an array of cognitive domains when learning science online, including students' effort, focus, and time management. Students reported that the fast pace of online courses, the lack of needing to show up to a class in person, and difficulty developing relationships with other students commonly exacerbated their depression. Conversely, the flexibility of completing course work when and where students wanted, developing a relationship with the instructor, and the ease of having questions answered online positively affected students' depression. This study provides insight into ways to create inclusive online learning environments for students with depression.

INTRODUCTION

Increasingly, college students report struggling with depression, and colleges and universities are beginning to recognize the importance of improving undergraduate mental health (Mistler *et al.*, 2012; National Council on Disability, 2017; Center for Collegiate Mental Health, 2020; Hsu and Goldsmith, 2021). Depression is defined as frequent feelings of unhappiness, hopelessness, and often a loss of motivation or interest in actions that an individual previously enjoyed (American Psychiatric Association, 2013). In the United States, depression is believed to affect about 23% of college students (American College Health Association, 2020). However, some studies estimate that depression affects a far greater percentage of undergraduates (Garlow *et al.*, 2008; Mohammed *et al.*, 2021). Additionally, depression rates among college students are currently estimated to be at an all-time high, likely due to the emotional stress caused by the COVID-19 pandemic (Kecojevic *et al.*, 2020; Kujawa *et al.*, 2020; Son *et al.*, 2020; Wang *et al.*, 2020; Lee *et al.*, 2021).

College students perceive that depression can have a detrimental effect on their grades and ability to complete college courses (American College Health Association, 2019). Indeed, studies have shown that students with depression taking in-person courses underperform on assessments compared with students without depression (Hysenbegasi *et al.*, 2005; DeRoma *et al.*, 2009; Yasin and Dzulkifli, 2011). There are multiple explanations as to why depression may affect student performance. Depression has been shown to negatively affect one's executive function, which is

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defined as one's ability to coordinate thoughts and actions when working toward a goal (Miller and Wallis, 2009). As such, difficulties with executive function can make goal setting and goal achievement difficult (Boyd and Reuning-Elliott, 1998; Meltzer and Krishnan, 2007). In addition, students with depression are at risk for experiencing stereotype threat in academic environments (Quinn *et al.*, 2004). Stereotype threat refers to the risk of confirming negative stereotypes about a group that one belongs to (Steele and Aronson, 1995); if students with depression perceive that others think that individuals with mental health conditions struggle academically, they may underperform compared with their counterparts without mental health conditions when they perceive their intelligence is being evaluated (Spencer *et al.*, 1999). As researchers strive to further understand the experiences of college students with depression and create more inclusive academic environments, it is important to note that the majority of extant research regarding the experience and performance of undergraduates with depression has taken place in traditional, in-person courses (Hysenbegasi *et al.*, 2005; DeRoma *et al.*, 2009; Yasin and Dzulkifli, 2011).

Notably, depression affects undergraduates in academic environments beyond the traditional in-person classroom. For example, in an interview study of 35 undergraduate researchers with depression, participants described that depression can have a negative impact on their motivation, productivity, creativity, and concentration when engaging in undergraduate research experiences (Cooper *et al.*, 2020a). In turn, the unstructured nature of research and the increased opportunities to experience failure often exacerbated depression among these undergraduate researchers. Depression has also been shown to affect undergraduates in study abroad programs. One study found that students were likely to express a negative mood if they perceived their study abroad experience as less challenging and their environment as more hostile and anxiety provoking (Savicki, 2013). Finally, there is emerging evidence that depression may also affect students who complete college courses online. A recent study found that needing to have the camera on, struggling to get to know the instructor, the potential for distractions to occur during online learning, the potential for surroundings to embarrass someone while on camera, and working with people one does not know increased feelings of anxiety among students with depression engaging in online college science courses (Mohammed *et al.*, 2021).

The impact of online learning on students with depression is of particular interest given the increasing number of colleges and universities adopting online courses, especially considering the transition to online learning due to the COVID-19 pandemic (Son *et al.*, 2020). Before the pandemic, many universities already offered completely online degree programs in science disciplines, reflecting the rapid growth in online education in recent years (Allen and Seaman, 2013; Varty, 2016; Cooper *et al.*, 2019; Mead *et al.*, 2020). Indeed, students have increasingly engaged in online learning experiences in the last two decades, leveraging the flexibility and accessibility that online courses provide (Song *et al.*, 2004; Northrup, 2009; Daymont *et al.*, 2011; Daniel, 2016; Soffer *et al.*, 2019). Prior research suggests that depression persists as a significant concern for online students as well as for in-person students (Lindsey *et al.*, 2009; Beiter *et al.*, 2015; Sifat, 2020; Mohammed *et al.*, 2021). A survey of 1886 students pursuing undergraduate degrees across an array of disciplines through an online university found that 32.1% of respondents indicated that they had been diagnosed with depression (Krasowski, 2018). In fact, depression may be more prevalent in online environments; compared with in-person degree programs, online degree programs often serve individuals who are disproportionately likely to experience depression, including women (Evans *et al.*, 2018; Pelayo, 2018; Mead *et al.*, 2020), first-generation college students (Jenkins *et al.*, 2013; Mead *et al.*, 2020), individuals from low socioeconomic backgrounds (Eisenberg *et al.*, 2007; Mead *et al.*, 2020), members of the LGBTQ+ community (Eisenberg *et al.*, 2007; Evans *et al.*, 2018), and people with disabilities (Turner and Noh, 1988).

Engaging in online science courses is thought to be challenging for students in general (Kim *et al.*, 2005; Song *et al.*, 2004). Science courses have been described as extremely rigorous, stressful, and competitive (Everson *et al.*, 1993; Strenta *et al.*, 1994; Seymour and Hunter, 2019), and students pursuing both science, technology, engineering, and mathematics (STEM) majors and non-STEM majors report that it is more difficult to pay attention and learn science content in online courses compared with in-person courses (Mohammed *et al.*, 2021). Further, adapting to novel learning environments can cause any student to feel unsure about their skills (Bennett and Lockyer, 2004; Cameron and Rideout, 2020), and online students across disciplines frequently describe experiencing technological issues (Song *et al.*, 2004; Smith, 2005; Bonk *et al.*, 2018; Olt and Teman, 2018; Mohammed *et al.*, 2021), which can lead to irritability and a disinterest in learning (Tank, 2020).

We hypothesize that students with depression may be particularly susceptible to experiencing challenges in online college science courses. Theories of depression provide some insight as to why specific aspects of online courses may exacerbate depression. However, no theory is widely accepted as an overarching framework that fully explains depression. As such, we draw from two prominent sets of theories to further understand the relationship between online science courses and student depression: The *behavioral theories* of depression posit that depression is a result of one's interactions with one's environment, resulting from decreased reward, negative reinforcement, and encouragement of depressive or passive behaviors (Lewinsohn, 1974; Martell *et al.*, 2001; Carvalho *et al.*, 2011). The *cognitive theories* of depression, which suggest that one's way of thinking, particularly having a negative view of oneself, the world, and the future, can result in distorted thoughts and depressive symptoms (Beck, 1979; Leahy, 2002). Together, these sets of theories help explain why particular aspects of online courses, may exacerbate depressive symptoms among undergraduates.

Drawing from the behavioral and cognitive theories of depression (Lewinsohn, 1974; Beck, 1979; Martell *et al.*, 2001; Leahy, 2002; Carvalho *et al.*, 2011) and the limited research on the experiences of undergraduate science students with depression (Cooper *et al.*, 2020a,b), we hypothesize that aspects of learning science online related to *success/failure*, *social relationships/isolation*, and *flexibility* may affect depression among undergraduates. While failure, which we define as the inability to meet the demands of an achievement (Henry *et al.*, 2019), can be difficult for any undergraduate (Gin *et al.*, 2018; Henry *et al.*, 2019, 2021), recent research found that encountering

failure has been reported to be particularly difficult for science undergraduates with depression (Cooper *et al.*, 2020a). Specifically, cognitive theories of depression (Beck, 1979; Leahy, 2002) support the findings from a study of undergraduate researchers with depression; these students reported focusing excessively on a failure, inappropriately blaming themselves for a failure, and perceiving a failure as a reflection of their broader abilities to be successful (Cooper *et al.*, 2020a). In the context of learning science online, we posit that aspects of science courses that relate to whether a student might fail an assignment or exam, such as having difficulty getting questions answered and the sometimes fast pace of online courses, may exacerbate student depression. Additionally, behavioral theories of depression (Lewinsohn, 1974) and prior research (Santini *et al.*, 2015; Cooper *et al.*, 2020a; Gin *et al.*, 2021b) suggest that the extent to which science students can form social relationships that result in positive reinforcement would be protective against depression, while isolation can exacerbate depressive symptoms. Students report it is notoriously difficult to develop relationships with other students and instructors in online courses (Mohammed *et al.*, 2021); as such, we predict this may negatively affect depression. Finally, the flexibility of not having to show up to class in person may present difficulties for undergraduates during a depressive episode; being required to be physically present in an education space may provide motivation for students to accomplish activities of daily living (ADL), defined as basic self-care tasks such as bathing, grooming, and dressing, which can be difficult for individuals with depression (Kazama *et al.*, 2011). However, the relationship between flexible science academic environments and depression is complex (Cooper *et al.*, 2020a; Gin *et al.*, 2021b). There are instances in which the flexibility of completing academic work from where students want and when students want could be helpful for depression. For example, studies have shown that flexibility can be helpful for undergraduate science students with depression, because it affords them the ability to complete work when they feel best and avoid work when they are recovering from a depressive episode (Cooper *et al.*, 2020a,b). Additionally, not needing to be seen by others, whether via online conferencing platforms or in person, may be helpful for students who have been crying or who have been unable to complete ADLs (Tricker *et al.*, 2001). Why flexible academic environments are sometimes helpful and sometimes harmful for students with depression is not well studied; our previous work suggests that the severity of one's depression may partially explain these conflicting findings; students who are moderately depressed may benefit from the motivation of needing to show up somewhere in person, while students undergoing a major depressive episode may benefit from the flexibility needed to recover from severe symptoms (Cooper *et al.*, 2020a; Gin *et al.*, 2021b), although more research is needed.

In addition to aspects of online courses affecting undergraduate depression, we also hypothesize that depression may in turn make the process of learning online especially difficult for students. For example, depression can negatively affect students' cognitive domains, including their attention and time management, language and communication skills, executive function, problem solving, and social interactions (Grabinger *et al.*, 2008), and studies have found that students from STEM disciplines may report more difficulty paying attention, staying motivated, and managing their time in online courses compared to in-person courses due to experiencing higher levels of anxiety (Mohammed *et al.*, 2021). Additionally, online courses are thought to have fewer student–student and student–instructor interactions compared with in-person courses (Jaggars, 2014), primarily owing to the lack of opportunities for informal conversations online (Contreras-Castillo *et al.*, 2004). The lack of interaction with peers and faculty can make learning more difficult (McBeath *et al.*, 2018; Mohammed *et al.*, 2021) and results in feelings of isolation and loneliness that can exacerbate depression (Cooper *et al.*, 2020a; Gin *et al.*, 2021b). In sum, learning science online may exacerbate students' depression, and in turn, students' depression may affect their abilities to learn science online.

CURRENT STUDY

Given the increase in the number of online science courses and the potential for depression to affect students' experiences in their learning environments, we designed a study to examine how students perceive their depression affects their ability to learn science online, and in turn, how students perceive online college science courses affect their depression. Our specific research questions were:

1. To what extent do undergraduates perceive depression affects cognitive domains related to learning science online?
2. What aspects of online college science courses do undergraduates perceive exacerbate their depression?
3. What aspects of online college science courses do undergraduates perceive help their depression?

METHODS

This study was conducted with an approved Arizona State University Institutional Review Board protocol (no. 12862).

Study Context and Participants

Students who identified as having depression were recruited from a large, public research-intensive (R1) institution in the southwestern United States in the Fall 2020 semester. This specific institution offers students the opportunity to earn a BS in biological sciences in two ways: (1) through an in-person degree program or (2) through an online degree program. We intentionally recruited students who were enrolled in the completely online BS degree program in biological sciences. The degree requirements of each program are identical, but the online courses are most commonly offered over 7.5 weeks, while in-person courses are most commonly offered over 15 weeks. However, online students are advised to take half as many courses at a time compared with in-person students, because the courses are accelerated. Additionally, all online courses are offered asynchronously, meaning that students are not required to meet for class at a particular time.

We chose to recruit students from the online program because the focus of the study was to explore the relationship between students' experiences in online science courses and depression. This study was conducted in Fall 2020, which was during the COVID-19 pandemic, shortly after the death of George Floyd and the rise of the Black Lives Matter movement, and during a polarizing U.S. presidential election. While it is expected that one or more of these events likely contributed to

each student's mental health (Dreyer *et al.*, 2020; Kecojevic *et al.*, 2020; Kibbey *et al.*, 2020; Ni *et al.*, 2020), examining such impact was beyond the scope of our study. Therefore, at the beginning of each interview, we informed students that we wanted to focus this study exclusively on the relationship between online learning and depression. We also explicitly asked students to discuss their depression as it related to aspects of online science courses that were present before, and would likely be present after, the COVID-19 pandemic (see the interview script in the Supplemental Material). We felt as though targeting this population of online students strengthened the study, as the mode of course delivery did not change as a result of COVID-19 for our participants; these students had been enrolled in online college science courses before and during the pandemic. Additionally, these students were exposed to many more online courses than in-person students who had only taken online courses for a semester or two solely as a result of COVID-19. While we only recruited students from the BS in biological sciences program, we asked students about their experiences in online science courses broadly.

Interviews

In Fall 2020, we sent a survey out to all instructors of biology courses within the online BS in biological sciences degree program and asked them to share it with their students. At the end of the survey, students were asked if they would be interested in participating in a follow-up interview. Of the 595 students who completed the survey, 492 indicated interest in participating in an interview (82.7%), 153 of whom identified as having depression (31.1%). We sent an email to each of the 153 students explaining that we were interested in interviewing students with depression about their experiences in online college science courses. We did not require students to be formally diagnosed with depression in order to participate in the interview, as we know that mental health care is disproportionately unavailable to Black and Latinx individuals as well as those coming from low-income backgrounds (Howell and McFeeters, 2008; Kataoka *et al.*, 2011; Santiago, 2013). Of the 153 students with depression who were contacted, 24 students (15.7%) agreed to participate in the interview.

Research has established that depression can negatively affect one's cognitive domain, which can in turn affect learning (Grabinger *et al.*, 2008; Vives *et al.*, 2015). As such, we asked students how they perceived their depression affects cognitive domains commonly associated with learning in the context of online college science courses (Grabinger *et al.*, 2008; Vives *et al.*, 2015). Specifically, we drew from research that has outlined five cognitive domains that can be affected by depression and that are hypothesized to specifically affect student learning in online environments (Grabinger *et al.*, 2008): 1) attention and memory, which are related to perception, concentration, and regulation of emotion during learning; 2) language, which is related to students expressing ideas during class; 3) executive function, which includes time management and monitoring progress toward course goals; 4) problem solving, which encompasses strategizing and critical thinking; and 5) social function, defined as one's ability to form social and professional relationships (Grabinger *et al.*, 2008).

In the interview, we chose to explore the impact of depression on attention and memory symptoms by asking students about their *memory*, *focus*, and *effort*, the impact of depression on language symptoms by asking students about their *ability to communicate their thoughts in an online course*, and the impact of depression on executive function by asking about *time management* and *goal setting in an online environment*. We also asked directly about students' abilities to *problem solve* and their *social interactions*. We probed to what extent students perceived that their depression affected each of these factors in the context of learning science online.

We also asked students whether specific aspects of online courses worsened their depression and whether specific aspects helped them manage their depression. We did not intend to identify aspects of courses that were entirely unique to online courses, but used the extant literature to identify aspects of online courses that were commonly associated with student affective outcomes and would likely affect student depression based on behavioral and cognitive theories of depression (Lewinsohn, 1974; Beck, 1979) as well as prior research on undergraduates with depression (Cooper *et al.*, 2020a,b). The specific aspects of online courses that we asked about were identified as aspects of online courses that related to failure: 1) struggling to have questions about course material answered and 2) the fast pace of online courses; isolation: 3) struggling to make connections with other students and 4) struggling to communicate or connect with an instructor; and flexibility: 5) not needing to show up to a class in person. In contrast, we hypothesized that the converse of some of these factors related to success (as opposed to failure) and social relationships (as opposed to isolation) may be protective against student depression: success: 1) having questions about course material answered; social relationships: 2) making connections with other students and 3) making connections or communicating with an instructor. Additionally, because of the complex relationship between flexibility and depression, we anticipated that the flexible nature of online course may also be helpful for students' depression: flexibility: 4) flexibility to learn on one's own time and 5) feeling a sense of anonymity in online courses. Each of these factors has been identified in the literature as an aspect of online courses that can affect how students feel; a table of each factor, whether it is hypothesized to affect depression negatively or positively, and the corresponding citation(s) is included in the Supplemental Material.

During the interview, we first asked students whether they had ever experienced a particular aspect of an online science course (e.g., struggling to have their questions answered) that we hypothesized may affect their depression. Notably, the students in this study are completing their degrees completely online, and all but one had taken at least three online college science courses, with more than half having taken at least five online college science courses by the time they completed these interviews. As such, students had experienced opposite aspects of online science courses (e.g., difficulty developing relationships with other students as well as the ease of developing relationships with other students) during their time in college. If students confirmed they had experienced a particular aspect, we then asked them how, if at all, it affected their depression. We chose to ask students about how specific aspects of online courses affected their depression, because we assumed that students had not likely thought about how online courses may affect their depression, and we predicted that directing their

attention to specific aspects of online courses may yield more fruitful responses (Warren, 2002; DiCicco-Bloom and Crabtree, 2006). To ensure that we did not miss any prominent aspects of online science courses that may affect student depression, we also asked open-ended questions about whether there were any additional aspects of online learning environments that students perceived affected their depression (Adamson *et al.*, 2004).

To establish cognitive validity of the interview questions, we conducted think-aloud interviews with two individuals who had recently graduated with a BS in biology, had completed online course work, and identified as having depression (Trenor *et al.*, 2011). The interview script was revised after the first think-aloud interview to improve interviewee understanding of the interview questions but functioned well during the second think-aloud interview and was not subsequently revised. A copy of the full interview script is provided in the Supplemental Material. Each interview was conducted via Zoom by one of two researchers (T.F.M. or L.E.G.). The average length of the interviews was about 1 hour, and students were compensated for their time with a $15 gift card.

Analysis

We used a hybrid approach of deductive and inductive coding to answer our research questions (Fereday and Muir-Cochrane, 2006). Specifically, the researchers used deductive coding to identify whether students experienced each of the five factors hypothesized to negatively affect their depression and each of the five factors hypothesized to positively affect depression, and also whether students reported that a factor they experienced affected their depression. Further, we identified whether each student reported that depression affected cognitive domains related to learning science online.

Inductive coding was used to analyze a question asking students whether any additional aspects of online college science courses negatively affected their depression and whether any additional factors positively affected their depression. We also used inductive coding to identify common themes about how specific factors affected depressive symptoms and to assess how students perceived depression affected their cognitive domains.

Two researchers (T.F.M. and K.M.C.) reviewed all interviews independently and took detailed analytic notes to identify themes that emerged from the interviews (Birks and Mills, 2015). They compared their notes and developed a detailed coding rubric of all themes they identified. Both researchers used the coding rubric to code a subset of five interviews (21% of interviews) and iteratively revised the codebook using constant comparison methods (Glesne, 2016). Using the final codebook (available in the Supplemental Material), two researchers (T.F.M. and N.J.W.) independently coded a randomly selected subset of eight interviews (33% of all interviews) and their Cohen's κ interrater score was at an acceptable level ($\kappa = 0.85$; Landis and Koch, 1977). One researcher (T.F.M.) coded the remaining interviews. Data saturation was reached with the current sample; therefore, we determined that no further recruitment was needed (Guest *et al.*, 2006). We chose not to examine trends in the data based on student demographics, because this was outside the scope of our research questions and not appropriate given the number of interviewees in the study (Vasileiou *et al.*, 2018). Quotes were lightly edited for clarity, and pseudonyms were given to all students to protect their privacy.

Author Positionality

Some of the authors identify as having depression and some do not. Two of the authors (T.F.M. and N.J.W.) have completed undergraduate online science courses; however, neither was enrolled in the online biological sciences program described in this study.

RESULTS AND DISCUSSION

We present the results and discussion together to elaborate on our findings and contextualize them within the extant literature. When presenting our results regarding which cognitive domains students perceive their depression affected when learning online, we chose to present quotes in a table, as the quotes did not need to be further contextualized to answer the respective research question. Conversely, we chose to embed quotes in text to represent reasoning students gave as to why aspects of online courses negatively and positively affected their depression. The content of the quotes provided was often reflective of the experiences of most students in the study, and thus we felt that contextualizing each quote would be helpful in fully explaining the perceptions of students in this study (Lingard, 2019).

Participant Demographics

Participants in the study were primarily women (79.2%), white (75.0%), continuing-generation college students (79.2%), transfer students (79.2%), and in their third or fourth year of college (83.3%). Students most commonly identified as having moderate (29.2%) or severe (45.8%) depression during the time that they have been enrolled in online college science courses, and 91.7% of participants had been diagnosed with depression. All but one student had completed at least three online college science courses.

Notably, because all students were enrolled in a fully online degree program, their demographics differ substantially from those of students who are enrolled in traditional in-person degree programs at this particular institution (Mead *et al.*, 2020). We found that students who agreed to participate in the study were representative of the broader population of the online program; these students are more likely to be women, older, first-generation college students, have higher financial need, and to begin their college careers at a different institution compared with undergraduates enrolled in the in-person biological sciences degree program at this particular institution (Mead *et al.*, 2020). A summary of student demographics is reported in Table 1, and additional student-level demographics can be found in the Supplemental Material.

Research Question 1: Student-Perceived Effect of Depression on Cognitive Domains Related to Online Learning

We asked students whether they perceived their depression affects their cognitive domains in the context of learning science online by asking them specifically about: effort, focus, time management, their ability to communicate thoughts, goal setting, problem solving, memory, and social interactions. Students most commonly reported that their depression affected their effort (100% of students), focus (95.8%), time management

TABLE 1. Demographics of interview participants, including personal demographics, depression demographics, and demographics related to their experience in online learning environments

Student-level demographics	Interview participants % (*n*) (*N* = 24)	Online learning demographics	Interview participants % (*n*) (*N* = 24)	Depression demographics	Interview participants % (*n*) (*N* = 24)
Gender		Number of online science courses		Severity of depression	
Woman	79.2 (19)	0 classes	0.0 (0)	Mild	20.8 (5)
Man	12.5 (3)	1–2 classes	4.2 (1)	Moderate	29.2 (7)
Other	8.3 (2)	3–4 classes	37.5 (9)	Severe	45.8 (11)
Race/ethnicity		5–6 classes	25.0 (6)	Extremely severe	4.2 (1)
Asian	4.2 (1)	7 or more classes	33.3 (8)	Diagnosed with depression	
Black	8.3 (2)	Length of online science courses[a]		Yes	91.7 (22)
Latinx	12.5 (3)	6 weeks	29.2 (7)	No	8.3 (2)
White	75.0 (18)	7.5 weeks	75.0 (18)	Treated for depression	
Transfer status		8 weeks	37.5 (9)	Yes	83.3 (20)
Transferred from a 2-year college	79.2 (19)	15 weeks	33.3 (8)	No	12.5 (3)
Transferred from a 4-year college	12.5 (3)			Decline to state	4.2 (1)
Non-transfer	8.3 (2)			Treatment for depression	
Financially stable				Medication	79.2 (19)
Yes, but only sometimes	54.2 (13)			Counseling	4.2 (1)
Yes	33.3 (8)			Decline to state	16.7 (4)
No	0.0 (0)				
Decline to state	12.5 (3)				
College generation status					
First generation	20.8 (5)				
Non–first generation	79.2 (19)				
Year in college					
First year	4.2 (1)				
Second year	12.5 (3)				
Third year	41.6 (10)				
Fourth year or greater	41.6 (10)				
Age					
Range	22–37				
Mean	28				
Primary caregiver					
Yes	29.2 (7)				
No	70.8 (17)				

[a]Students were asked to select any length of an online courses that they had completed, which is why the percentages add to more than 100%.

(95.8%), and ability to communicate their thoughts (95.8%), followed by their goal setting (83.3%) and problem solving (83.3%), and finally their memory (70.8%) and social interactions (70.8%; Table 2).

While to our knowledge no studies have examined the impact of depression on student performance in online courses, our findings suggest that depression may be particularly detrimental to students learning science in online environments, especially in the fast-paced, accelerated online courses that the majority of these students were referencing. Research suggests that elements of online education may require disproportionate use of cognitive domains compared with in-person education. For example, a study of more than 300 undergraduates who had completed both in-person and online college science courses showed that students perceived learning to be more difficult in online courses and that there are a number of distractions specific to learning in an online environment that likely require students to expend additional effort and focus (Mohammed *et al.*, 2021). Additionally, undergraduates highlight that online courses can be especially disorganized and unstructured (Mohammed *et al.*, 2021) and online learning requires high self-regulation (Kauffman, 2015) and self-discipline (Waschull, 2005; Gorbunovs *et al.*, 2016), which likely implies the need for time-management skills, because many online courses are asynchronous. Finally, students in this study acknowledge that making connections with instructors and students is substantially more difficult in online environments, which is also supported by other studies (Aragon, 2003; Bejerano, 2008; Erichsen and Bolliger, 2011; Gillett-Swan, 2017). Given the potential for depression to

TABLE 2. Percent of students who reported that their depression affects a particular cognitive domain in the context of online science courses and example quotes.

Cognitive domains	% (*n*) (*N* = 24)	Example quote 1	Example quote 2
Effort	100.0 (24)	Deja: "If I'm in a depressive state, I'm just trying to get [course work] turned in, whether it's going to be adequate or not. If you're in a depressive state, it usually diminishes the amount of effort that you try to put in."	Stephanie: "If I'm having an episode of depression, I'll put less effort in and it makes the depression worse, because once again, I'm not doing my best work and things just go down the hole."
Focus	95.8 (23)	Hailey: "[Depression] makes it hard to get started [on online homework]. Sometimes I have to be very deliberate about setting aside time to focus. If I know I have enough or too much time ahead of me and I just don't feel motivated to do it, then I have a much harder time focusing [online]."	Charlie: "[Depression] can definitely be a drain on focus because if I'm having a particularly bad episode, it's hard to do anything at all."
Time management	95.8 (23)	Lindsay: "Sometimes those [depressive] episodes can last for two or three weeks and with the accelerated [online] platform, that can be over half of the course [that] I am depressed. And so, it makes it easy to push stuff off till the last minute because you're just falling behind, then you're just stuck. You fell behind [a] bunch of weeks in a row and now my grade got hit."	Maddison: "When [the online class] is fast-paced I do need to read and reread, the shortened semesters do impact me negatively just because I've spent so much more time on this one assignment that I could have completed two instead of the one."
Communicate thoughts	95.8 (23)	Heather: "When I'm depressed, I don't want to speak at all. Sometimes I feel like I almost can't talk, I go into my little bubble. I really just want to be isolated and quiet in those moments. That can be hard, especially if [instructors] want you to sit there and actually chat on video with peers or something. I feel like that's difficult."	Deja: "If I'm in a depressive state, I try not to contribute to the course, because when you're in a depressive state, you feel inadequate. You feel that your opinion is not strong enough to contribute to a college course, and that maybe you should just sit back and listen to other people and just let them put their thoughts in the forefront. You have a lot of self-doubt in your ability, you try to find the answer on your own because you don't want other people to think that you're ignorant or that you don't know. So, you either find out the answer on your own or you just try to progress forward without knowing the answer."
Goal setting	83.3 (20)	Emily: "When it comes to long-term [goals], that's where my brain sometimes just goes, 'Well, what's the point? What are you doing this for? Do you really think you're going to be able to finish this degree? When are you going to do this for next semester?' It's the short-term goals that are crazier and more haphazard but it's almost the long-term goals that are the deeper, more hurtful moments."	Sofia: "When taking accelerated online courses, I know I'm going to have a breakdown. (...) I try and compartmentalize as much as I can and give myself like little itty-bitty goals, but it's going to overflow at the end of it. So, I get in a fight or flight mode, and the whole time I'm just setting little mini goals for myself throughout the entire class, because if I don't, then I will definitely fail."
Problem solving	83.3 (20)	Allison: "I'm just not thinking very clearly if I'm depressed, I'm not using the full amount of my knowledge because I'm so stressed out. I'm not giving the best answer that I could because something's holding me back in my head."	Hannah: "Oh, God. It's horrible. If I'm depressed, I can't problem solve at all. My mind is so off in La La Land with myself, that it's very hard for me to be able to problem solve."
Memory	70.8 (17)	Lindsay: "I will have to reread things over and over. (…) [It's] super frustrating because I can't remember things I'm doing at that moment, and I have to read out loud to myself and take all of these extra steps just to remember something very basic."	John: "You need a certain amount of time and practice to really commit things to memory. You don't always have the time, energy and motivation to practice as much as you should. A lot of it is 'okay just get it done by the deadline, just get it done.' And when you do that, every week for seven and a half weeks, you don't commit anything to memory you're just treading water. You're not swimming to shore."
Social interactions	70.8 (17)	Heather: "I will cancel a lot of things. I just felt like I didn't have the energy to be presentable enough to, like, talk to people on Zoom and I didn't have the energy to fake it and, like, joke and chat, and I don't like to be that person who is kind of a downer when I talk to people. If I'm depressed, I try to hide it from people."	Lindsay: "It's hard to engage with people when you feel [depressed]. When [in person], you don't really have a choice, so it's easy to pull out of it, because I know I need to be a participating member of society. But when no one's there to see me do it, then I just don't do it."

TABLE 3. Aspects of online college science courses that negatively affect undergraduate depression

Aspects of online courses	Description	Students who reported experiencing the factor as part of their online courses % (*n*/*N*)	Students who reported experiencing the factor and identified that it negatively affected their depression % (*n*/*N*)[a]
Fast pace of online courses	Online courses at this institution are generally 3 credits over 7.5 weeks, which means the content is covered approximately twice as fast as it is during in-person courses.	100.0 (24/24)	100.0 (24/24)
Not needing to show up to class in person	All course work is taken online asynchronously and students do not need to show up to a physical classroom.	100.0 (24/24)	66.7 (16/24)
Difficulty developing a relationship with other students	Student struggles to develop a relationship with other students in the online environment, often because of a lack of face-to-face interactions.	87.5 (21/24)	95.2 (20/21)
Difficulty communicating or developing a relationship with the instructor	Student struggles to communicate or develop a relationship with the instructor in the online environment, often because of a lack of informal conversations.	83.3 (20/24)	95.0 (19/20)
Difficulty having questions answered	Student struggles to have questions answered in an online environment.	75.0 (18/24)	100.0 (18/18)
Lack of structure and accountability of online courses[b]	Many online courses have guidelines and not due dates, which puts students in charge of determining the schedule outlining when each assignment should be accomplished.	45.8 (11/24)	100.0 (11/11)

[a]Each denominator indicates the number of students who reported that they experienced each aspect of an online course.
[b]All factors were predetermined, with the exception of the lack of structure and accountability of online courses, which emerged from students' responses to a question asking if there were any additional aspects of online college science courses that exacerbated their depression.

negatively impact student learning in online science courses, identifying aspects of online courses that exacerbate or alleviate depression may be integral to improving learning for this specific group of undergraduates.

Research Question 2: Aspects of Online Courses That Can Exacerbate Undergraduate Depression

We asked students about specific aspects of online science courses that we hypothesized would exacerbate their depression. We report the number of interviewees who confirmed that they had experienced a particular aspect in an online college science course, as well as the percent who reported that the aspect had a negative effect on their depression in Table 3. We explore here student explanations for why specific aspects of online science courses negatively affect their depression.

Students described that aspects of online courses related to failure, particularly the fast pace of online courses as well as struggling to have content questions answered, exacerbated their depression. Specifically, all students in the study identified that the fast pace of online science courses worsened their depression. For example, students like Abigail and John described that fast-paced courses can cause them to fall behind, which in turn can cause them to be critical of themselves or can decrease their motivation, making it even more difficult to catch up on their online course work.

> Abigail: "Once you start falling behind, then the depression kicks in, it will make me think less of myself for that. Then it's even harder to catch up. As the things pile up, it gets more difficult to pull myself out of [the depression]."

> John: "[Completing science courses online over a short period of time] felt like trying to fill up a water balloon with a fire hydrant. When you don't have a lot of motivation, it's very difficult. It's a constant uphill struggle. It was already very difficult when I was severely depressed to get the motivation to do things on time. (…) So it feels like you're struggling to tread water and they just keep pouring more in so what's the point if you know you're just going to drown? It's hard to even begin to try when you feel like you've already failed."

Depression is highly related to burnout, defined as a chronic stress syndrome involving emotional exhaustion and reduced personal accomplishment (Maslach *et al.*, 2001; Bianchi *et al.*, 2014). While burnout is typically associated with one's career, we argue that students in this study described symptoms of burnout as it relates to their course work. For example, students like Abigail and John highlight that the fast pace of online courses can cause them to fall behind, which appears to lead to a state of mental exhaustion. Time constraints and management of multiple deadlines are considered to be common academic stressors (DeRoma *et al.*, 2009), which can lead to a circular relationship wherein such stressors and depression may intensify one another (Heiligenstein *et al.*, 1996), as described by Abigail and John.

In addition, three-quarters of students struggled to have their questions answered in their online college science courses, and all of these students described that this worsened their depression. Students, like John, described that when they struggled to have their questions answered they sometimes blamed themselves, which exacerbated their depression.

> John: "[Not having my questions] answered feels crushing because it feels like once again you weren't good enough to get your questions answered or you were stupid and you didn't ask the right question."

John's reaction to not having his questions answered by the instructor may be common among students with depression. Research shows that individuals with depression often blame themselves for rejection (or perceived rejection), whereas this is less common for individuals without depression (Abramson and Sackheim, 1977; Janoff-Bulman, 1979; Gilbert and Miles, 2000). As such, if instructors unintentionally fail to answer a student's question, this may have an unintended but significant impact on a student with depression. Further, feeling as though they were unable to have questions answered caused some students to experience helplessness and a "depression spiral." Specifically, Abigail describes this spiral; she explains how struggling to have a question answered led to an increasing number of negative thoughts.

> Abigail: "[Not having my questions answered] can start a spiral because if I'm confused and I've been working on [my course work] and my only option is to ask the teacher, and that option isn't working, then I feel completely helpless. And that helplessness is one of the worst parts of the depression. (…) [The depression spiral] starts with something small [like not having my question answered], and then that feeds into a thought of, 'Oh, I'm having trouble with this assignment,' and then it goes to, 'Oh, I'm having trouble [with] this whole course,' and then it goes to, 'Well, I'm just stupid,' and it goes to 'Well, I'll never do anything,' which goes to 'Well, I might as well just quit doing this completely.' So, it just gets bigger and worse. A domino effect."

Abigail's reaction to not having her questions answered can be partially explained by ideas presented in the hopelessness theory of depression (Abramson *et al.*, 1989), which posits that one's negative cognitive styles combined with a negative event (such as not having a question answered) can engender a sense of hopelessness (Joiner *et al.*, 2005). Providing online students with multiple outlets to have their questions answered, such as the option to email teaching assistants, submit questions through online platforms such as Blackboard or Canvas, or even to reach out to fellow students on more informal communication platforms such as WhatsApp, Discord, or GroupMe may help alleviate this issue for students (Kam and Hoop, 2013; Xiu and Thompson, 2020).

Additionally, we hypothesized that aspects of online courses that may contribute to feelings of social isolation may also contribute to students' depression. A well-established challenge of online college learning environments is promoting community among students (Aragon, 2003; Anderson-Rowland *et al.*, 2004; Shea *et al.*, 2006; Erichsen and Bolliger, 2011). While a lack of student–student relationships in college has been suggested to negatively affect undergraduates (Rovai and Wighting, 2005; Croxton, 2014; Xerri *et al.*, 2018), we were interested in understanding how a lack of relationships in the context of online courses affected depression. Nearly 88% of participants in our study reported struggling to develop relationships with other students in their online science courses, and 95.8% of those students identified that this negatively affected their depression. Students, like Jenna and Dakota, often described that struggling to develop relationships with other students made them feel isolated, which worsened their depression.

> Jenna: "I haven't made any friends at all. Like there's no one-on-one communication or even group communication with other students. It just kind of made the feelings of disconnection and isolation more intense. It made it harder for me to feel motivated to study."

> Dakota: "Online there's no face, there's no real person. It's just a block of text to be able to communicate with someone. (…) It feels a lot more distant and hard to communicate. It doesn't really feel like there are other students in the course. It becomes a lot more lonely, a lot more isolating."

Students' perceptions that the isolation exacerbated their depression aligns with a review of studies in psychiatry, which found that being connected to a large number of people is protective against depression (Santini *et al.*, 2015). Further, life sciences undergraduates have reported that feelings of isolation worsened their depression in the context of research experiences (Cooper *et al.*, 2020a). Unfortunately, developing relationships with other students has been found to be particularly difficult for students in online courses (Jaggars, 2014), and our study further supports this notion.

Relatedly, 83.3% of students confirmed that they struggled to develop relationships with instructors of their online science courses, and 95.0% of those students perceived that this worsened their depression. Students commonly described that not connecting with an instructor made them feel as though nobody cares or as though they did not belong in science. Hannah describes that these feelings ultimately led her to give up trying in her science course.

> Hannah: "Not being able to connect with [the instructor] (…) I just felt like he didn't want me there. It definitely impacted my depression a lot because I was like 'Why am I even here?' It affected me the whole time to the point that I just gave up [and failed the class]."

This study adds to a growing body of literature that suggests that developing student–instructor relationships is difficult in an online environment (Hara and Kling, 1999; Woods, 2002; Vonderwell, 2003; Song *et al.*, 2004; Swan *et al.*, 2006; Boling *et al.*, 2012; Jaggars, 2014; Shaw *et al.*, 2015). However, researchers have examined ways to build instructor immediacy, defined as the perception of physical and psychological intimacy between students and instructors (Mehrabian, 1971), and some strategies that have been shown to build instructor immediacy in person can likely be implemented in online courses, such as using humor (Gorham and Christophel, 1990; Cooper *et al.*, 2018) and using students' names when calling on or conversing with students (Cooper *et al.*, 2017). Additionally, studies have identified strategies to build instructor immediacy in the specific context of online courses, including hosting small-group discussions during class (Kam and Hoop, 2013), consistently providing feedback to students (Sher, 2009), interacting with students on required discussion board posts (Redmond and Lock, 2006), and interfacing with students

during virtual office hours (Haythornthwaite, 2006; Lowenthal *et al.*, 2017; Alawamleh *et al.*, 2020). Based on our data, we hypothesize that these efforts may be disproportionately beneficial for students with depression, given how the lack of relationship with an instructor can have a detrimental impact on their belonging in science. Further, behavioral theories of depression would suggest that, if these relationships provide positive reinforcement, it may further protect students from experiencing depressive symptoms (Lewinsohn, 1974; Martell *et al.*, 2001; Carvalho *et al.*, 2011).

In addition to aspects of online science courses that are related to failure and social isolation, we hypothesized that the flexible nature of online courses, particularly not needing to show up to class in person, may exacerbate depression. Indeed, two-thirds of the participants reported that this worsened their depression because they struggled to feel motivated to engage in activities of daily living or ADLs as described by Valeria.

> Valeria: "[Not needing to show up to class in person] makes [my depression] worse because I don't have a reason to leave the house and I don't have a reason to shower or any of that. It makes it [so] that I can just completely be a shut-in."

It is well established that individuals with major depression sometimes experience difficulties accomplishing ADLs (Kazama *et al.*, 2011). Unlike in-person courses that may motivate students to engage in ADLs to avoid being negatively evaluated by others (Tricker *et al.*, 2001), it seems that asynchronous online courses may not elicit a fear of negative evaluation, as students are not required to see anyone while completing the course. Further, a study of 276 students taking online courses investigated why students did not turn on their cameras and found that the most frequent reason reported is students being concerned about personal appearance, often because of unbrushed hair or wearing pajamas (Castelli and Sarvary, 2021). This highlights a novel way that in-person social interactions may positively benefit students that is noticeably absent in online asynchronous environments that do not require students to be visible to others.

After examining students' experiences with the five predetermined online factors that we hypothesized would negatively affect their depression, we asked students if there were any additional aspects of online courses that affected their depression. Forty-five percent of students described that another aspect of online courses related to the flexibility, the lack of structure, and accountability of online courses worsened their depression. Specifically, students like Maya explained that online courses are often self-paced in that the instructor sets a due date (often the end of the semester) when all work needs to be submitted. As such, it is up to the students to structure their time so that their course work is completed. Students described that this lack of structure and accountability worsened their depression.

> Maya: "You are on your own terms, you got to be your own cheerleader, I guess, you got to keep up with your own schedule. There's no class you go to regularly, it's kind of all work on your own. So, you can easily get behind, and that can make you get really sad."

A lack of structure has also been shown to worsen depression among life sciences graduate students, because a lack of guidance for what needs to be done and when something should be completed can hinder motivation (Gin *et al.*, 2021a). Relatedly, major depression can make goal setting and goal achievement difficult (Boyd and Reuning-Elliott, 1998; Watkins and Brown, 2002). Researchers have found that individuals with depression develop less-detailed goals and less-specific explanations for approaching a goal than individuals who do not have depression (Dickson and Moberly, 2013), which helps explain why students reported the lack of structure and lack of accountability in online science courses as troublesome for their depression.

Research Question 3: Aspects of Online Courses That Can Help Undergraduate Depression

In addition to identifying aspects of online college science courses that negatively affect student depression, we also identified aspects that positively affect depression. We report the number of interviewees who reported experiencing each aspect, as well as the percent who reported that the aspect had a positive effect on their depression in Table 4.

Students confirmed that aspects of online science courses that minimized their chances of failing (or maximized their chances for success) were protective against their depression; 95.8% students described that at some point they were easily able to get their questions answered in this context, and nearly 96% of these students said that this positively affected their depression. Abigail, who earlier described that not having her questions answered could lead to a depressive spiral, highlighted how a simple response from an instructor can not only stop the spiral, but can also cause her to feel supported.

> Abigail: "There's been certain teachers where they're really good at responding quickly to the things on the forums. It's just such a light. If I'm starting to spiral, if I'm starting to go into that negative thought pattern and I post something and almost immediately get a response, then it's a hard shock. I'm like, 'Oh, okay. I have a solution. I can figure it out.' It's crazy actually how quickly the spinning can stop as soon as there's another direction introduced. A lot of it is just getting that feedback, that sign that you are going in the right direction, that you're not alone in this project. And if you start to fail, there will be someone there to throw you a life jacket. Even if it isn't so much about that one assignment, just feeling supported in general in the class is really helpful."

Participants' responses further support that providing students with multiple outlets to have questions answered may be particularly impactful for students with depression.

Additionally, opportunities to build relationships with instructors and fellow students and avoid feeling socially isolated also positively affected depression. All students acknowledged instances when they were able to build a relationship with an instructor online and/or easily communicate with an instructor online, and all confirmed that this positively affected their depression, which aligns with previous literature highlighting the positive impact that student–instructor relationships can have on students (Sher, 2009; Nguyen, 2015; Cooper *et al.*, 2018; Parnes *et al.*, 2020). For example, Heather describes how connecting with an instructor made her feel less alone and

TABLE 4. Aspects of online college science courses that positively affect undergraduate depression

Aspects of online courses	Description	Students who reported experiencing the factor as part of their online courses % (*n*/*N*)	Students who reported experiencing the factor and identified that it positively affected their depression % (*n*/*N*)[a]
Flexibility to learn on your own time	Online courses often allow for flexibility regarding when and where students want to complete online science course work.	100.0 (24/24)	100.0 (24/24)
Communicating or developing a relationship with the instructor	Student experiences clear communication or easily develops a relationship with the instructor.	100.0 (24/24)	100.0 (24/24)
Ease having questions answered	Student is easily able to have questions answered in the online environment.	95.8 (23/24)	95.7 (22/23)
Anonymity	Student is able to be anonymous in the online environment.	95.8 (23/24)	87.0 (20/23)
Developing a relationship with other students	Student is able to develop a relationship with other students in the online environment.	79.2 (19/24)	100.0 (19/19)

[a]Each dominator indicates the number of students who reported that they experienced each aspect of an online course.

that an instructor can help change a student's mood and self-confidence.

> Heather: "[Getting to know the instructor] just makes you feel like you're not alone. Like, somebody cares, you have somebody that's willing to connect with you and understand you. When you're depressed, I think a lot of the time you feel very alone and misunderstood, like nobody gets it, you can't really explain it, it's difficult. So, I think that makes a difference in your mood and just the way that you feel about yourself, because it can be the difference between feeling like you're worthless and you're a terrible student, and why can't you get things together, too. I've felt like that, and then had a good conversation with an instructor who understands, and then it totally pulls me out of that mood and makes me feel like I actually am capable of being productive, and it's not just me struggling with these things."

Feeling alone or misunderstood, as Heather describes, can be common among individuals with depression (Matthews *et al.*, 2016), which helps explain why a lack of a student–instructor relationship can be so problematic, while a short, positive interaction has the potential to have a lasting effect.

Nearly 80% of students highlighted that they were sometimes able to develop relationships with other students online, and all of those students said this also had a positive impact on their depression. For example, Sam described that connecting with other students helped him realize that he had similar interests to other students, which positively impacted his mood. He also highlighted that developing those relationships inspired him to complete ADLs and communicate with others.

> Sam: "Having that positive reinforcement, learning that you're not doing this alone, there's other people that are in the same program as you or interested in the same things is huge for [my depression]. Making a connection was huge, I did it in a few of my classes where we set up study groups, had online face-to-face Zoom meetings, went over homework assignments and things, and that was really nice. (…) I need to get my butt up, put on a shirt, something, do my hair, and just talk to people about things, whatever we're working on."

While developing relationships with peers generally positively impacts students (Urdan and Schoenfelder, 2006; Kiuru *et al.*, 2015; Ryan *et al.*, 2019), this finding suggests that such relationships may be especially impactful in online environments, where students can often feel isolated (Aragon, 2003; Erichsen and Bolliger, 2011; Gillett-Swan, 2017; Kaplan-Rakowski, 2021; Orr, 2019). Indeed, studies have suggested that building peer support online can lead to a strong sense of belonging (Thomas *et al.*, 2014), increases support for learners (Galvin, 2012), and enhances student satisfaction with their online experience (Fuller *et al.*, 2015).

When investigating the relationship between the flexible nature of online courses and depression, we found that all but one student in the study agreed that they had the opportunity to be anonymous in their online college science courses, meaning they had the option to not show their face when completing online science course work. Nearly 87% of students said that this positively impacted their depression. Students, like Claire, often highlighted how depression affected their ability to execute ADLs like brushing their hair, so not having to be on camera for a particular day was helpful. Further, students described that when they are depressed, it is sometimes visible, because they look sad or have been crying. Students often feel uncomfortable revealing their depression to others (Cooper *et al*., 2020b), so it is helpful when they can remain anonymous or unseen.

> Claire: "It's comforting that I can have a bad day and that I can show up with my hair not brushed and be crying and have makeup down my face, and no one can see me."

This finding may appear to contradict students' perceptions that not needing to go to class in person can be detrimental because it does not motivate them to complete ADLs. However, most students, like Claire, seemed to be referencing extremely bad days when which they would not be able to complete their ADLs regardless of their level of motivation. Further, all interview participants reported that online college science courses that are delivered asynchronously afford them the flexibility of learning on their own time, meaning that they are often able to learn online when and where they want. Interestingly, all students described that this could positively affect their depression. Students, like Deja, commonly described that this flexibility allowed them to tend to their depressive symptoms when they needed to.

> Deja: "The flexibility really alleviates those symptoms brought on by the depression. It helps because if I'm in a depressive episode, not having to show up allows me to focus that time on getting out of that depression, on figuring out what my triggers are, and dealing with them so that I can continue to be successful in my course."

Similarly, John described that not having to be in class at a certain time means that his depression does not negatively affect his grades by decreasing attendance points.

> John: "If you don't have the motivation to do things [the flexibility of online work] is great because you don't have to go to class. There is no mandatory attendance policy where if you miss one you start being anxious and sad that you messed up. But eventually, you have to get out of bed to eat. It's okay if you'd have to start your homework at four o'clock in the afternoon. It doesn't matter, you still get your homework done and you didn't miss class."

While a complete lack of structure and not having to show up in person seemed to have a negative effect on students' depression, the flexibility to take some time off during a depressive episode seemed to positively impact students like Deja and John. A similar trend was found in an interview study of 50 life sciences PhD students with depression. Students described that the unstructured nature of PhD programs negatively impacts their depression, because it increases their need to be motivated and set their own goals, which can be difficult during a depressive episode (Gin *et al.*, 2021b). However, the flexibility of deciding when to do their research allowed them time to recover from depressive episodes or seek medical treatment during the day. As such, creating online science courses that are structured with clear deadlines but that also have built-in flexibility that could accommodate students during a depressive episode would likely be helpful for students with depression (Gin *et al.*, 2021a). No additional themes emerged from the open-ended question asking whether any other aspects of online science courses had a positive impact on students' depression.

GENERAL DISCUSSION

In this study, we aimed to understand to what extent students perceive depression affects their cognitive domains when learning science online and identify aspects of online college science courses that affect student depression. We used the existing literature to identify a set of five aspects of online courses that we hypothesized might exacerbate student depression and five aspects that we hypothesized might help student depression. The data that emerged from the interviews revealed trends about overarching components of online education, success/failure, social relationships/isolation, and flexibility and the nuanced ways in which they affect depression and how depression, in turn, can affect student learning. Additionally, the analysis of the data spurred ideas for how institutions may make their online science courses more inclusive for students with depression.

Success/Failure

Cognitive theories of depression, particularly the hopelessness theory of depression, suggest that individuals with depression are prone to feeling as though they are not in control of events; feeling as though one is not in control of negative events is defined as "hopelessness" (Abramson *et al.*, 1989). Our study identified that seemingly small aspects of online science courses, such as students being unable to have a question about content answered, can fuel feelings of hopelessness regarding success in the course. Conversely, having questions answered appeared to stop depressive feelings from spiraling and avoided the development of hopelessness.

Relationships with Other Students and Instructors

The experiences of students in this study reflect those of prior studies highlighting the importance of individuals with depression building strong social networks (Santini *et al.*, 2015; Cooper *et al.*, 2020a,b; Gin *et al.*, 2021b). Specifically, having social support can be protective against depression (Charles *et al.*, 2021) and this may be especially important in online college science courses. At this particular institution, a study found that online life sciences undergraduates lacked opportunities that are traditionally associated with going to college, such as participating in community service, leadership positions, and undergraduate research experiences (Cooper *et al.*, 2019). Further, these online students were significantly less likely to develop relationships with students and faculty members compared with their peers pursuing in-person degrees (Cooper *et al.*, 2019). As such, students pursuing fully online degrees may be particularly prone to experiencing social isolation, which is likely disproportionately difficult for individuals with depression.

Flexibility of Online Learning

The unique flexibility that online learning affords students is one of the primary reasons why students seek out online college courses (McLoughlin and Oliver, 2000; Song *et al.*, 2004; Sit *et al.*, 2005; Appana, 2008; Yukselturk and Yildirim, 2008; Northrup, 2009; Daymont *et al.*, 2011; Daniel, 2016; Soffer *et al.*, 2019; Stone *et al.*, 2019). We found aspects related to such flexibility have differing impacts on depression. Specifically, students explained that the opportunity to learn when and where they wanted afforded them opportunities to recover from depressive episodes, which can be integral in helping students maximize their productivity upon re-engaging with course work (Judd *et al.*, 2000; Cooper *et al.*, 2020a,b). The opportunity to remain anonymous in online courses also

positively impacted student depression, which aligns with previous research showing that individuals with depression value maintaining anonymity (Levine *et al.*, 2003), especially if they are concerned about repercussions resulting from an unintentional reveal of their depression (Cooper *et al.*, 2020b). Conversely, the lack of needing to show up to class in person and the lack of concrete due dates emerged as aspects of online learning that students with depression struggled with, likely owing to difficulty that individuals with depression can experience with motivation and goal setting (Street, 2002; Huang *et al.*, 2016).

How Depression May Affect Student Learning

Given that students overwhelmingly agreed that their depression negatively affected cognitive domains and that these functions may be particularly integral to learning online (Grabinger *et al.*, 2008), identifying ways to craft more inclusive online learning environments for individuals with depression is important for maximizing their academic experiences. Further, creating online science learning spaces where individuals with depression can thrive is an integral step to developing a more inclusive scientific enterprise, given that depression disproportionately affects individuals who are underrepresented and underserved in science (Turner and Noh, 1988; Eisenberg *et al.*, 2007; Jenkins *et al.*, 2013; Evans *et al.*, 2018; Flaherty, 2018; Mead *et al.*, 2020; National Science Foundation, 2021).

Recommendations to Create More Inclusive Online Science Courses for Undergraduates with Depression

Maximizing Students' Control of Their Success. Helping students feel in control of their success in a course is an important step in creating inclusive online college science courses. As such, ensuring that students have multiple ways to have questions answered (e.g., use of discussion boards, ability to email the instructor, using platforms such as Slack or WhatsApp) will likely reduce depressive symptoms by helping students avoid feeling hopeless regarding their understanding of science content. Further, the fast-paced nature of online courses is often inevitable, especially when institutions require online courses to be offered over an accelerated time period (e.g., 7.5 weeks instead of 15 weeks). Instructors can acknowledge this at the beginning of courses, so that students are aware of this challenge. This may also allow students with depression who are registered with the disability resource centers at their institutions to proactively identify accommodations that will be helpful as they navigate a particular course (Gin *et al.*, 2020).

Facilitating Social Relationships. We recommend that instructors make efforts to not only build relationships between themselves and students, but also provide opportunities to cultivate relationships among students in online science courses. Instructors could facilitate instructor–student relationships and engage students by sending electronic communications to students, incorporating humor into the course (Cooper *et al.*, 2018; Lei *et al.*, 2010), using student names in email correspondence (Cooper *et al.*, 2017), and interacting with students through discussion boards or virtual office hours (Alawamleh *et al.*, 2020; Haythornthwaite, 2006; Lowenthal *et al.*, 2017). Displaying a positive attitude and clearly communicating expectations regarding students' work are also ways instructors could foster relationships with their online students (Webb and Barrett, 2014).

Managing Flexibility. Identifying the level of flexibility that is ideal for students with depression is difficult, and it seems that this ideal level may be different for each student depending on the severity of the individual's depressive symptoms. However, common themes from student interviews indicate that students thrive when they have structure and accountability (e.g., having some deadlines as opposed to having all work due at the end of the semester). In contrast, some aspects of flexible online courses seemed to be generally helpful for depression, particularly allowing students to be anonymous during class and to complete work when they want (although this may conflict with the previously noted necessary amounts of structure in courses for other students). Creating a structured course with deadlines but inviting students to ask for an extension if their mental health is interfering with their ability to meet a deadline may serve as a possible solution.

Limitations and Future Directions

Our sample of students enrolled in a completely online biological sciences degree program is unique; students enrolled in this program are more likely to be women, older, and/or first-generation college students and to have higher financial need compared with undergraduates enrolled in an in-person BS in biological sciences degree program at this particular institution (Mead *et al.*, 2020). As such, these findings should not be generalized beyond this particular student population. Relatedly, these students are online students, meaning that they were enrolled in online college science courses before and during the COVID-19 pandemic. We hypothesize that students with depression who were in in-person programs and completed online college science courses during the pandemic may share many experiences with the participants in this study, but likely faced additional challenges related to rapidly adapting to a new mode of learning in response to the pandemic (Mohammed *et al.*, 2021).

The primary focus of the study was to document the experiences of students with depression and not to compare their experiences with those without depression; interviewing students within a marginalized group with the intent to capture their experience without comparing it to that of the majority group is common practice in biology education research (Cooper and Brownell, 2016; Cooper *et al.*, 2020a,b; Pfeifer *et al.*, 2021). However, future studies may want to assess how the particular aspects of online education that we report on in this study affect students without depression. A sample size of 24 students may be perceived as small. However, a sample of this size is common among other exploratory qualitative biology education studies (Cooper and Brownell, 2016; Cooper *et al.*, 2017; Chatterjee *et al.*, 2019; Daniels *et al.*, 2019; Downing *et al.*, 2020; Pfeifer *et al.*, 2021). Additionally, we reached saturation in our data within the first 16 interviews, as is expected in qualitative studies (Guest *et al.*, 2006), and therefore we did not perceive that recruiting additional students with depression would change our findings. We acknowledge that students' depressive feelings may change each day, which may influence their responses to interview questions. However, we encouraged students to speak about their depression, on

average, during their time taking online college science courses. It was neither feasible nor within the scope of our study to examine whether there were demographic differences among students' experiences with depression in online science courses. We do propose that examining how student demographics affect their experience with depression in online science courses in a large-scale quantitative study would be an important step in creating a more diverse and inclusive scientific community. While we chose to examine our research questions within the confined context of online college science courses, we did not identify any finding that we hypothesize is specific to college science. Large-scale quantitative studies across different majors could examine this further.

Conclusion

In this interview study, we examined the experiences of undergraduate students with depression in online science courses. We probed how students perceived their depression affected their learning, and in turn, how online science courses negatively and positively affected students' depression. Students commonly perceived that their depression negatively affected their ability to learn science online by interfering with their effort, focus, time management, ability to communicate thoughts, goal setting, problem solving, memory, and social interactions. Students also commonly agreed that struggling to develop relationships with instructors and students, struggling to have questions answered, not needing to show up to class in person, the lack of structure and accountability and the fast nature of online courses negatively affected their depression. Conversely, developing relationships with instructors and other students, having questions answered promptly, engaging in science courses anonymously, and being able to learn when and where a student wants positively impacted their depression.

Important Note

Resources are available for individuals who are experiencing depression. Most colleges and universities have crisis hotlines and counseling services designed to provide students, staff, and faculty with treatment for depression, which can often be found on the institution's website. Furthermore, there are free 24/7 services such as Crisis Text Line, which allows you to text a trained live crisis counselor (Text "CONNECT" to 741741 (Text Depression Hotline, 2021), and phone hotlines such as the National Suicide Prevention Lifeline at 1-800-273-8255 (TALK). Additionally, the Anxiety and Depression Association of America website, https://adaa.org (Anxiety and Depression Association of America, 2021), and the Depression and Bipolar Support Alliance, http://dbsalliance.org (Depression and Bipolar Support Alliance, 2021), provide helpful information if you want to learn about depression, learn about help for depression, or learn about depression resources near you.

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