The Experience of Undergraduate with Depression in Online Science Learning Environments

by

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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, I interviewed 24 undergraduates with depression who were pursuing an online BS degree in biological sciences at a research-intensive institution. I 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, I 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 coursework 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.

DEDICATION

To my family, my mom, dad, sister and brothers, for supporting me throughout my academic journey and for motivating me at every point along the way to pursue my passions. To the mentors, colleagues, and students who have inspired my thinking and caused me to ponder deliberately about equity and access in science education.

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CHAPTER 1

THE EXPERIENCE OF UNDERGRADUATE WITH DEPRESSION IN ONLINE SCIENCE LEARNING ENVIRONMENTS

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 consistently increase each year (Center for Collegiate Mental Health, 2017) and 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 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; Flaherty, 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). Indeed, 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; 2020b), 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 sometimes the 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; Cooper et al., 2020b; 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; Cooper et al., 2020b). Additionally, not needing to see 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) are 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 (κ = 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

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.

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)**
<u>Gender</u>		**<u>Number of Online Science Courses</u>**		**<u>Severity of Depression</u>**	

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)
Decline to state	12.5 (3)				
College generations 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 (Standard Deviation)	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%.

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 (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 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.

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 [coursework] 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 [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 know it's like a schedule to break down because 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 course % (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 three credits over seven in a half 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 coursework 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	87.5 (21/24)	95.2 (20/21)

	face interactions.		
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 their 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.

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 oneon-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.

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 course % (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 coursework.	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	Student is easily	95.8 (23/24)	95.7 (22/23)

questions answered	able to have their questions answered in the online environment.		
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.			

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 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). 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.

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).

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, and 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.

REFERENCES

Abramson, L. Y., Metalsky, G. I., & Alloy, L. B. (1989). Hopelessness depression: A theory-based subtype of depression. *Psychological Review*, *96*(2), 358.

Abramson, L. Y., & Sackheim, H. A. (1977). A paradox in depression: Uncontrollability and self-blame. *Psychological Bulletin*, *84*(5), 838.

Adamson, J., Gooberman-Hill, R., Woolhead, G., & Donovan, J. (2004). "Questerviews": Using questionnaires in qualitative interviews as a method of integrating qualitative and quantitative health services research. *Journal of Health Services Research & Policy*, *9*(3), 139–145.

Alawamleh, M., Al-Twait, L. M., & Al-Saht, G. R. (2020). The effect of online learning on communication between instructors and students during Covid-19 pandemic. *Asian Education and Development Studies*.

Allen, I. E., & Seaman, J. (2013). *Changing course: Ten years of tracking online education in the United States.* ERIC.

Ambawati, R., Putri, E. K., Rahayu, D. A., & Khaleyla, F. (2021). Science online learning during the covid-19 pandemic: Difficulties and challenges. *Journal of Physics: Conference Series*, *1747*(1), 012007.

American College Health Association. (2019). NCHA-II_SPRING_2019_UNDERGRADUATE_REFERENCE_GROUP_DATA_REPORT.pdf www.acha.org/documents/ncha/NCHA-II_SPRING_2019_UNDERGRADUATE_REFERENCE_GROUP_DATA_REPORT.pdf

American College Health Association. (2020). NCHA-III_FALL_2020_UNDERGRADUATE_REFERENCE_GROUP_DATA_REPORT.pdf https://www.acha.org/documents/ncha/NCHA-III_Fall_2020_Undergraduate_Reference_Group_Data_Report.pdf

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5*. Washington, DC: American Psychiatric Association.

Anderson-Rowland, M. R., Vanis, M., Zerby, D. M., Chain, E. L., Banks, D. L., & Mater, B. (2004). METS pilot program: A community college/university collaboration to recruit underrepresented minority students into engineering. *Proceedings of the 2004 American Society for Engineering Education Annual Conference*.

Anxiety and Depression Association of America. (2021). Anxiety and Depression Association of America, ADAA. https://adaa.org/

Appana, S. (2008). A review of benefits and limitations of online learning in the context of the student, the instructor and the tenured faculty. *International Journal on E-Learning*, *7*(1), 5–22.

Aragon, S. R. (2003a). Creating social presence in online environments. *New Directions for Adult and Continuing Education*, *2003*(100), 57–68.

Aragon, S. R. (2003b). Creating social presence in online environments. *New Directions for Adult and Continuing Education*, *2003*(100), 57–68.

Armstrong-Mensah, E., Ramsey-White, K., Yankey, B., & Self-Brown, S. (2020). COVID-19 and distance learning: Effects on Georgia State University school of public health students. *Frontiers in Public Health*, *8*, 547.

Beiter, R., Nash, R., McCrady, M., Rhoades, D., Linscomb, M., Clarahan, M., & Sammut, S. (2015). The prevalence and correlates of depression, anxiety, and stress in a sample of college students. *Journal of Affective Disorders*, *173*, 90–96.

Bejerano, A. (2008). Face-to-face or online instruction? Face-to-face is better. *Communication Currents*, *3*(3), 1–3.

Bennett, S., & Lockyer, L. (2004). Becoming an online teacher: Adapting to a changed environment for teaching and learning in higher education. *Educational Media International*, *41*(3), 231–248.

Bianchi, R., Schonfeld, I. S., & Laurent, E. (2014). Is burnout a depressive disorder? A reexamination with special focus on atypical depression. *International Journal of Stress Management*, *21*(4), 307.

Birks, M., & Mills, J. (2015). *Grounded theory: A practical guide*. Sage.

Boling, E. C., Hough, M., Krinsky, H., Saleem, H., & Stevens, M. (2012). Cutting the distance in distance education: Perspectives on what promotes positive, online learning experiences. *The Internet and Higher Education*, *15*(2), 118–126.

Bonk, C. J., Kirkley, J., Hara, N., & Dennen, V. P. (2018). Finding the instructor in post-secondary online learning: Pedagogical, social, managerial and technological locations. In *Teaching & Learning Online* (pp. 76–97). Routledge.

Boyd, B. K., & Reuning-Elliott, E. (1998). A measurement model of strategic planning. *Strategic Management Journal*, *19*(2), 181–192.

Cameron, R. B., & Rideout, C. A. (2020). 'It's been a challenge finding new ways to learn': First-year students' perceptions of adapting to learning in a university environment. *Studies in Higher Education*, 1–15.

Castelli, F. R., & Sarvary, M. A. (2021). Why students do not turn on their video cameras during online classes and an equitable and inclusive plan to encourage them to do so. *Ecology and Evolution*, *11*(8), 3565–3576.

Center for Collegiate Mental Health. (2017). State College, PA: Penn State University.

Center for Collegiate Mental Health. (2020). State College, PA: Penn State University.

Chatterjee, D., Ford, J. K., Rojewski, J., & Watts, S. W. (2019). Exploring the impact of formal internships on biomedical graduate and postgraduate careers: An interview study. *CBE—Life Sciences Education*, *18*(2), ar20.

Colvin, J. W., & Ashman, M. (2010). Roles, risks, and benefits of peer mentoring relationships in higher education. *Mentoring & Tutoring: Partnership in Learning*, *18*(2), 121–134.

Contreras-Castillo, J., Favela, J., Pérez-Fragoso, C., & Santamaría-del-Angel, E. (2004). Informal interactions and their implications for online courses. *Computers & Education*, *42*(2), 149–168.

Cooper, K. M., & Brownell, S. E. (2016). Coming out in class: Challenges and benefits of active learning in a biology classroom for LGBTQIA students. *CBE—Life Sciences Education*, *15*(3), ar37.

Cooper, K. M., Gin, L. E., Barnes, M. E., & Brownell, S. E. (2020). An exploratory study of students with depression in undergraduate research experiences. *CBE—Life Sciences Education*, *19*(2), ar19.

Cooper, K. M., Gin, L. E., & Brownell, S. E. (2019). Diagnosing differences in what Introductory Biology students in a fully online and an in-person biology degree program know and do regarding medical school admission. *Advances in Physiology Education*, *43*(2), 221–232.

Cooper, K. M., Gin, L. E., & Brownell, S. E. (2020). Depression as a concealable stigmatized identity: What influences whether students conceal or reveal their depression in undergraduate research experiences? *International Journal of STEM Education*, *7*, 1–18.

Cooper, K. M., Haney, B., Krieg, A., & Brownell, S. E. (2017). What's in a name? The importance of students perceiving that an instructor knows their names in a high-enrollment biology classroom. *CBE—Life Sciences Education*, *16*(1), ar8.

Cooper, K. M., Hendrix, T., Stephens, M. D., Cala, J. M., Mahrer, K., Krieg, A., Agloro, A. C., Badini, G. V., Barnes, M. E., & Eledge, B. (2018). To be funny or not to be funny: Gender differences in student perceptions of instructor humor in college science courses. *PloS One*, *13*(8), e0201258.

Croxton, R. A. (2014). The role of interactivity in student satisfaction and persistence in online learning. *Journal of Online Learning and Teaching*, *10*(2), 314.

Daniel, J. (2016). Making sense of flexibility as a defining element of online learning. *Athabasca University*.

Daniels, N., Gillen, P., Casson, K., & Wilson, I. (2019). STEER: Factors to consider when designing online focus groups using audiovisual technology in health research. *International Journal of Qualitative Methods*, *18*, 1609406919885786.

Daymont, T., Blau, G., & Campbell, D. (2011). Deciding between traditional and online formats: Exploring the role of learning advantages, flexibility, and compensatory adaptation. *Journal of Behavioral and Applied Management*, *12*(2), 156.

Depression and Bipolar Support Alliance. (2021). Depression and Bipolar Support Alliance. https://www.dbsalliance.org/

DeRoma, V. M., Leach, J. B., & Leverett, J. P. (2009). The relationship between depression and college academic performance. *College Student Journal*, *43*(2), 325–335.

DiCicco-Bloom, B., & Crabtree, B. F. (2006). The qualitative research interview. *Medical Education*, *40*(4), 314–321.

Dickson, J. M., & Moberly, N. J. (2013). Reduced specificity of personal goals and explanations for goal attainment in major depression. *PloS One*, *8*(5), e64512.

Disability, N. C. on. (2017). *Mental health on college campuses: Investments, accommodations needed to address student needs*.

Downing, V. R., Cooper, K. M., Cala, J. M., Gin, L. E., & Brownell, S. E. (2020). Fear of negative evaluation and student anxiety in community college active-learning science courses. *CBE—Life Sciences Education*, *19*(2), ar20.

Dreyer, B. P., Trent, M., Anderson, A. T., Askew, G. L., Boyd, R., Coker, T. R., Coyne-Beasley, T., Fuentes-Afflick, E., Johnson, T., & Mendoza, F. (2020). The death of George Floyd: Bending the arc of history toward justice for generations of children. *Pediatrics*, *146*(3).

Duru, E., & Balkis, M. (2014). The roles of academic procrastination tendency on the relationships among self doubt, self esteem and academic achievement. *Egitim ve Bilim*, *39*(173).

Duta, N., Panisoara, G., & Panisoara, I.-O. (2015). The Effective Communication in Teaching. Diagnostic study regarding the academic learning motivation to students. *Procedia-Social and Behavioral Sciences*, *186*, 1007–1012.

Eisenberg, D., Gollust, S. E., Golberstein, E., & Hefner, J. L. (2007). Prevalence and correlates of depression, anxiety, and suicidality among university students. *American Journal of Orthopsychiatry*, *77*(4), 534–542.

Erichsen, E. A., & Bolliger, D. U. (2011). Towards understanding international graduate student isolation in traditional and online environments. *Educational Technology Research and Development*, *59*(3), 309–326.

Evans, T. M., Bira, L., Gastelum, J. B., Weiss, L. T., & Vanderford, N. L. (2018). Evidence for a mental health crisis in graduate education. *Nature Biotechnology*, *36*(3), 282–284.

Everson, H. T., Tobias, S., Hartman, H., & Gourgey, A. (1993). Test anxiety and the curriculum: The subject matters. *Anxiety, Stress, and Coping*, *6*(1), 1–8.

Fedynich, L. V. (2013). Teaching beyond the classroom walls: The pros and cons of cyber learning. *Journal of Instructional Pedagogies*, *13*.

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods*, *5*(1), 80–92.

Flaherty, C. (2018). New study says graduate students' mental health is a "crisis." *Inside HigherEd*, *6*.

Frisby, B. N., & Martin, M. M. (2010). Instructor–student and student–student rapport in the classroom. *Communication Education*, *59*(2), 146–164.

Fuller, M. B., Holzweiss, P., & Joyner, S. A. (2015). The importance of peer connections in Distance Education. *INSTRUCTIONAL TECHNOLOGY*, 15.

Galvin, R. J. (2012). Peer support: Enhancing the online learning experience. *International Journal of Innovation and Learning*, *12*(1), 41–53.

Garlow, S. J., Rosenberg, J., Moore, J. D., Haas, A. P., Koestner, B., Hendin, H., & Nemeroff, C. B. (2008). Depression, desperation, and suicidal ideation in college students: Results from the American Foundation for Suicide Prevention College Screening Project at Emory University. *Depression and Anxiety*, *25*(6), 482–488. https://doi.org/10.1002/da.20321

Gilbert, P., & Miles, J. N. (2000). Sensitivity to Social Put-Down: It's relationship to perceptions of social rank, shame, social anxiety, depression, anger and self-other blame. *Personality and Individual Differences*, *29*(4), 757–774.

Gillett-Swan, J. (2017). The challenges of online learning: Supporting and engaging the isolated learner. *Journal of Learning Design*, *10*(1), 20–30.

Gin, L. E., Guerrero, F. A., Brownell, S. E., & Cooper, K. M. (2021). COVID-19 and Undergraduates with Disabilities: Challenges Resulting from the Rapid Transition to Online Course Delivery for Students with Disabilities in Undergraduate STEM at Large-Enrollment Institutions. *CBE—Life Sciences Education*, *20*(3), ar36.

Gin, L. E., Wiesenthal, N. J., Ferreira, I., & Cooper, K. M. (2021). PhDepression: Examining How Graduate Research and Teaching Affect Depression in Life Sciences PhD Students. *CBE—Life Sciences Education*, *20*(3), ar41.

Glazier, R. A. (2016). Building rapport to improve retention and success in online classes. *Journal of Political Science Education*, *12*(4), 437–456.

Glesne, C. (2016). *Becoming qualitative researchers: An introduction*. ERIC.

Gorbunovs, A., Kapenieks, A., & Cakula, S. (2016). Self-discipline as a key indicator to improve learning outcomes in e-learning environment. *Procedia-Social and Behavioral Sciences*, *231*, 256–262.

Gorham, J., & Christophel, D. M. (1990). The relationship of teachers' use of humor in the classroom to immediacy and student learning. *Communication Education*, *39*(1), 46–62.

Grabinger, R. S., Aplin, C., & Ponnappa-Brenner, G. (2008). Supporting learners with cognitive impairments in online environments. *TechTrends*, *52*(1), 63–69.

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods*, *18*(1), 59–82.

Hara, N., & Kling, R. (1999). *Students' frustrations with a web-based distance education course*.

Haythornthwaite, C. (2006). Facilitating collaboration in online learning. *Journal of Asynchronous Learning Networks*, *10*(1), 7–24.

Heiligenstein, E., Guenther, G., Hsu, K., & Herman, K. (1996). Depression and academic impairment in college students. *Journal of American College Health*, *45*(2), 59–64.

Hoffman, E. M. (2014). Faculty and student relationships: Context matters. *College Teaching*, *62*(1), 13–19.

Howell, E., & McFeeters, J. (2008). Children's mental health care: Differences by race/ethnicity in urban/rural areas. *Journal of Health Care for the Poor and Underserved*, *19*(1), 237–247.

Hsu, J. L., & Goldsmith, G. R. (2021). Instructor strategies to alleviate stress and anxiety among college and University STEM Students. *CBE—Life Sciences Education*, *20*(1), es1.

Huang, Y., Lv, W., & Wu, J. (2016). Relationship between intrinsic motivation and undergraduate students' depression and stress: The moderating effect of interpersonal conflict. *Psychological Reports*, *119*(2), 527–538.

Humphrey, E. A., & Wiles, J. R. (2021). Lessons learned through listening to biology students during a transition to online learning in the wake of the COVID-19 pandemic. *Ecology and Evolution*, *11*(8), 3450–3458.

Hysenbegasi, A., Hass, S. L., & Rowland, C. R. (2005). The impact of depression on the academic productivity of university students. *Journal of Mental Health Policy and Economics*, *8*(3), 145.

Jaggars, S. S. (2014). Choosing between online and face-to-face courses: Community college student voices. *American Journal of Distance Education*, *28*(1), 27–38.

Janoff-Bulman, R. (1979). Characterological versus behavioral self-blame: Inquiries into depression and rape. *Journal of Personality and Social Psychology*, *37*(10), 1798.

Jenkins, S. R., Belanger, A., Connally, M. L., Boals, A., & Durón, K. M. (2013). First-generation undergraduate students' social support, depression, and life satisfaction. *Journal of College Counseling*, *16*(2), 129–142.

Joiner, T. E., Wingate, L. R., & Otamendi, A. (2005). An interpersonal addendum to the hopelessness theory of depression: Hopelessness as a stress and depression generator. *Journal of Social and Clinical Psychology*, *24*(5), 649–664.

Judd, L. L., Paulus, M. J., Schettler, P. J., Akiskal, H. S., Endicott, J., Leon, A. C., Maser, J. D., Mueller, T., Solomon, D. A., & Keller, M. B. (2000). Does incomplete recovery from first lifetime major depressive episode herald a chronic course of illness? *American Journal of Psychiatry*, *157*(9), 1501–1504.

Jurik, V., Gröschner, A., & Seidel, T. (2014). Predicting students' cognitive learning activity and intrinsic learning motivation: How powerful are teacher statements, student profiles, and gender? *Learning and Individual Differences*, *32*, 132–139.

Kam, R., & Hoop, B. (2013). Facilitating Inquiry-Based Science Learning Online in a Virtual University. *Higher Learning Research Communications*, *3*(2), 79–91.

Kaplan-Rakowski, R. (2021). Addressing students' emotional needs during the COVID-19 pandemic: A perspective on text versus video feedback in online environments. *Educational Technology Research and Development*, *69*(1), 133–136.

Kataoka, S., Jaycox, L. H., Wong, M., Nadeem, E., Langley, A., Tang, L., & Stein, B. D. (2011). Effects on school outcomes in low-income minority youth: Preliminary findings from a community-partnered study of a school trauma intervention. *Ethnicity & Disease*, *21*(3 0 1), S1.

Kauffman, H. (2015). A review of predictive factors of student success in and satisfaction with online learning. *Research in Learning Technology*, *23*.

Kazama, M., Kondo, N., Suzuki, K., Minai, J., Imai, H., & Yamagata, Z. (2011). Early impact of depression symptoms on the decline in activities of daily living among older Japanese: Y-HALE cohort study. *Environmental Health and Preventive Medicine*, *16*(3), 196–201.

Kecojevic, A., Basch, C. H., Sullivan, M., & Davi, N. K. (2020). The impact of the COVID-19 epidemic on mental health of undergraduate students in New Jersey, cross-sectional study. *PloS One*, *15*(9), e0239696.

Kibbey, M. M., Fedorenko, E. J., & Farris, S. G. (2020). Anxiety, depression, and health anxiety in undergraduate students living in initial US outbreak "hotspot" during COVID-19 pandemic. *Cognitive Behaviour Therapy*, 1–13.

Kilgore, W. (2016). Let's talk: Effectively Communicating with your Online Students. *Humanizing Online Teaching and Learning*.

Kim, K.-J., Liu, S., & Bonk, C. J. (2005). Online MBA students' perceptions of online learning: Benefits, challenges, and suggestions. *The Internet and Higher Education*, *8*(4), 335–344.

Kiuru, N., Aunola, K., Lerkkanen, M.-K., Pakarinen, E., Poskiparta, E., Ahonen, T., Poikkeus, A.-M., & Nurmi, J.-E. (2015). Positive teacher and peer relations combine to predict primary school students' academic skill development. *Developmental Psychology*, *51*(4), 434.

Krasowski, S. (2018). Canadian National College Health Assessment Survey: Report on responses from AU students. *Athabasca University.*

Kujawa, A., Green, H., Compas, B. E., Dickey, L., & Pegg, S. (2020). Exposure to COVID-19 pandemic stress: Associations with depression and anxiety in emerging adults in the United States. *Depression and Anxiety*, *37*(12), 1280–1288.

Landis, J. R., & Koch, G. G. (1977). An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics*, 363–374.

Lee, J., Jeong, H. J., & Kim, S. (2021). Stress, anxiety, and depression among undergraduate students during the COVID-19 pandemic and their use of mental health services. *Innovative Higher Education*, 1–20.

Lei, S. A., Cohen, J. L., & Russler, K. M. (2010). Humor on learning in the college classroom: Evaluating benefits and drawbacks from instructors' perspectives. *Journal of Instructional Psychology*, *37*(4), 326–332.

Levine, R. E., Breitkopf, C. R., Sierles, F. S., & Camp, G. (2003). Complications associated with surveying medical student depression. *Academic Psychiatry*, *27*(1), 12–18.

Lindsey, B. J., Fabiano, P., & Stark, C. (2009). The prevalence and correlates of depression among college students. *College Student Journal*, *43*(4).

Lingard, L. (2019). Beyond the default colon: Effective use of quotes in qualitative research. *Perspectives on Medical Education*, *8*(6), 360–364. https://doi.org/10.1007/s40037-019-00550-7

Lowenthal, P., Dunlap, J., & Snelson, C. (2017). Live synchronous web meetings in asynchronous online courses: Reconceptualizing virtual office hours. *Online Learning Journal*, *21*(4).

Maslach, C., Schaufeli, W. B., & Leiter, M. P. (2001). Job burnout. *Annual Review of Psychology*, *52*(1), 397–422.

Matthews, T., Danese, A., Wertz, J., Odgers, C. L., Ambler, A., Moffitt, T. E., & Arseneault, L. (2016). Social isolation, loneliness and depression in young adulthood: A behavioural genetic analysis. *Social Psychiatry and Psychiatric Epidemiology*, *51*(3), 339–348.

McBeath, M., Drysdale, M. T., & Bohn, N. (2018). Work-integrated learning and the importance of peer support and sense of belonging. *Education+ Training*.

McLoughlin, C., & Oliver, R. (2000). Designing learning environments for cultural inclusivity: A case study of indigenous online learning at tertiary level. *Australasian Journal of Educational Technology*, *16*(1).

Mead, C., Supriya, K., Zheng, Y., Anbar, A. D., Collins, J. P., LePore, P., & Brownell, S. E. (2020). Online biology degree program broadens access for women, first-generation to college, and low-income students, but grade disparities remain. *PloS One*, *15*(12), e0243916.

Mehrabian, A. (1971). *Silent messages* (Vol. 8). Wadsworth Belmont, CA.

Meltzer, L., & Krishnan, K. (2007). Executive function difficulties and learning disabilities. *Executive Function in Education: From Theory to Practice*, 77–105.

Miller, E. K., & Wallis, J. D. (2009). Executive function and higher-order cognition: Definition and neural substrates. *Encyclopedia of Neuroscience*, *4*(99–104).

Mistler, B. J., Reetz, D. R., Krylowicz, B., & Barr, V. (2012). The association for university and college counseling center directors annual survey. *Retrieved from Association for University and College Counseling Center Directors Website: Http://Files. Cmcglobal. Com/Monograph_2012_AUCCCD_Public. Pdf*.

Mohammed, T. F., Nadile, E. M., Busch, C. A., Brister, D., Brownell, S. E., Claiborne, C. T., Edwards, B. A., Gazing, W. J., Lunt, C., Tran, M., Vargas, C., Walker, K. M., Warkina, T. D., Witt, M. L., Zheng, Y., & Cooper, K. M. (2021). Aspects of large-enrollment online college science courses that exacerbate and alleviate student anxiety. *Under Review at CBE Life Sciences Education*.

Muilenburg, L. Y., & Berge, Z. L. (2005). Student barriers to online learning: A factor analytic study. *Distance Education*, *26*(1), 29–48.

National Science Foundation. (2021). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2021 | NSF - National Science Foundation*. https://ncses.nsf.gov/pubs/nsf21321

Nguyen, T. (2015). The effectiveness of online learning: Beyond no significant difference and future horizons. *MERLOT Journal of Online Learning and Teaching*, *11*(2), 309–319.

Ni, M. Y., Kim, Y., McDowell, I., Wong, S., Qiu, H., Wong, I. O., Galea, S., & Leung, G. M. (2020). Mental health during and after protests, riots and revolutions: A systematic review. *Australian & New Zealand Journal of Psychiatry*, *54*(3), 232–243.

Northrup, P. T. (2009). Online learners' preferences for interaction. *The Perfect Online Course: Best Practices for Designing and Teaching*, 463–473.

Olt, P. A., & Teman, E. D. (2018). A duoethnographic exploration of persistent technological failures in synchronous online education. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, *19*(3).

Orr, T. (2019). *Women with depression in online learning: A descriptive phenomenological analysis*.

Parnes, M. F., Suárez-Orozco, C., Osei-Twumasi, O., & Schwartz, S. E. (2020). Academic outcomes among diverse community college students: What is the role of instructor relationships? *Community College Review*, *48*(3), 277–302.

Paulsen, M. F., Nipper, S., & Holmberg, C. (2003). *Online education: Learning management systems: Global e-learning in a scandinavian perspective*.

Pfeifer, M. A., Reiter, E. M., Cordero, J. J., & Stanton, J. D. (2021). Inside and out: Factors that support and hinder the self-advocacy of undergraduates with ADHD and/or specific learning disabilities in STEM. *CBE—Life Sciences Education*, *20*(2), ar17.

Phirangee, K., Epp, C. D., & Hewitt, J. (2016). Exploring the Relationships between Facilitation Methods, Students' Sense of Community, and Their Online Behaviors. *Online Learning*, *20*(2), 134–154.

Quinn, K. A., Hugenberg, K., & Bodenhausen, G. V. (2004). Functional modularity in stereotype representation. *Journal of Experimental Social Psychology*, *40*(4), 519–527.

Redmond, P., & Lock, J. V. (2006). A flexible framework for online collaborative learning. *The Internet and Higher Education*, *9*(4), 267–276.

Reese, S. A. (2015). Online learning environments in higher education: Connectivism vs. dissociation. *Education and Information Technologies*, *20*(3), 579–588.

Rimm-Kaufman, S., & Sandilos, L. (2011). Improving students' relationships with teachers to provide essential supports for learning. *Teacher's Modules*.

Rovai, A. P., & Wighting, M. J. (2005). Feelings of alienation and community among higher education students in a virtual classroom. *The Internet and Higher Education*, *8*(2), 97–110.

Ryan, A. M., North, E. A., & Ferguson, S. (2019). Peers and engagement. In *Handbook of student engagement interventions* (pp. 73–85). Elsevier.

Santiago, D. A. (2013). Using a Latino Lens to Reimagine Aid Design and Delivery. *Excelencia in Education (NJ1)*.

Santini, Z. I., Koyanagi, A., Tyrovolas, S., Mason, C., & Haro, J. M. (2015). The association between social relationships and depression: A systematic review. *Journal of Affective Disorders*, *175*, 53–65.

Savicki, V. (2013). The effects of affect on study abroad students. *Frontiers: The Interdisciplinary Journal of Study Abroad*, *22*, 131–147.

Seymour, E., & Hunter, A.-B. (2019). Talking about leaving revisited. *Talking About Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education*.

Shaw, J., Kominko, S., & Terrion, J. L. (2015). Using LectureTools to enhance student–instructor relations and student engagement in the large class. *Research in Learning Technology*, *23*.

Shea, P., Li, C. S., & Pickett, A. (2006). A study of teaching presence and student sense of learning community in fully online and web-enhanced college courses. *The Internet and Higher Education*, *9*(3), 175–190.

Sher, A. (2009). Assessing the relationship of student-instructor and student-student interaction to student learning and satisfaction in web-based online learning environment. *Journal of Interactive Online Learning*, *8*(2).

Sifat, R. I. (2020). COVID-19 pandemic: Mental stress, depression, anxiety among the university students in Bangladesh. *Social Psychiatry*, *1*, 2.

Sit, J. W., Chung, J. W., Chow, M. C., & Wong, T. K. (2005). Experiences of online learning: Students' perspective. *Nurse Education Today*, *25*(2), 140–147.

Smith, T. C. (2005). Fifty-one competencies for online instruction. *The Journal of Educators Online*, *2*(2), 1–18.

Soffer, T., Kahan, T., & Nachmias, R. (2019). Patterns of students' utilization of flexibility in online academic courses and their relation to course achievement. *International Review of Research in Open and Distributed Learning*, *20*(3).

Son, C., Hegde, S., Smith, A., Wang, X., & Sasangohar, F. (2020). Effects of COVID-19 on college students' mental health in the United States: Interview survey study. *Journal of Medical Internet Research*, *22*(9), e21279.

Song, L., Singleton, E. S., Hill, J. R., & Koh, M. H. (2004). Improving online learning: Student perceptions of useful and challenging characteristics. *The Internet and Higher Education*, *7*(1), 59–70.

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology*, *35*(1), 4–28.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, *69*(5), 797.

Stone, C., Freeman, E., Dyment, J. E., Muir, T., & Milthorpe, N. (2019). Equal or equitable?: The role of flexibility within online education. *Australian and International Journal of Rural Education*, *29*(2), 26–40.

Street, H. (2002). Exploring relationships between goal setting, goal pursuit and depression: A review. *Australian Psychologist*, *37*(2), 95–103.

Strenta, A. C., Elliott, R., Adair, R., Matier, M., & Scott, J. (1994). Choosing and leaving science in highly selective institutions. *Research in Higher Education*, *35*(5), 513–547.

Swan, K., Shen, J., & Hiltz, S. R. (2006). Assessment and collaboration in online learning. *Journal of Asynchronous Learning Networks*, *10*(1), 45–62.

Tank, P. (2020). *Technical issues, pandemic trauma, lack of motivation, time management skills: Students suffer throu- Edexlive*. https://www.edexlive.com/news/2020/aug/25/technical-issues-pandemic-trauma--time-management-students-suffer-through-online-classes-14127.html

Text Depression Hotline. (2021). Crisis Text Line. https://www.crisistextline.org/

Thomas, L., Herbert, J., & Teras, M. (2014). *A sense of belonging to enhance participation, success and retention in online programs*.

Trenor, J. M., Miller, M. K., & Gipson, K. G. (2011). Utilization of a think-aloud protocol to cognitively validate a survey instrument identifying social capital resources of engineering undergraduates. *American Society for Engineering Education*.

Tricker, T., Rangecroft, M., Long, P., & Gilroy, P. (2001). Evaluating distance education courses: The student perception. *Assessment & Evaluation in Higher Education*, *26*(2), 165–177.

Turner, R. J., & Noh, S. (1988). Physical disability and depression: A longitudinal analysis. *Journal of Health and Social Behavior*, 23–37.

Urdan, T., & Schoenfelder, E. (2006). Classroom effects on student motivation: Goal structures, social relationships, and competence beliefs. *Journal of School Psychology*, *44*(5), 331–349.

Varty, A. K. (2016). Options for online undergraduate courses in biology at American colleges and universities. *CBE—Life Sciences Education*, *15*(4), ar58.

Vasileiou, K., Barnett, J., Thorpe, S., & Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: Systematic analysis of qualitative health research over a 15-year period. *BMC Medical Research Methodology*, *18*(1), 1–18.

Vives, M., López-Navarro, E., García-Campayo, J., & Gili, M. (2015). Cognitive impairments and depression: A critical review. *Actas Esp Psiquiatr*, *43*(5), 187–193.

Vonderwell, S. (2003). An examination of asynchronous communication experiences and perspectives of students in an online course: A case study. *The Internet and Higher Education*, *6*(1), 77–90.

Wang, X., Hegde, S., Son, C., Keller, B., Smith, A., & Sasangohar, F. (2020). Investigating mental health of US college students during the COVID-19 pandemic: Cross-sectional survey study. *Journal of Medical Internet Research*, *22*(9), e22817.

Warren, C. A. (2002). Qualitative interviewing. *Handbook of Interview Research: Context and Method*, *839101*.

Waschull, S. B. (2005). Predicting success in online psychology courses: Self-discipline and motivation. *Teaching of Psychology*, *32*(3), 190–192.

Watkins, E., & Brown, R. G. (2002). Rumination and executive function in depression: An experimental study. *Journal of Neurology, Neurosurgery & Psychiatry*, *72*(3), 400–402.

Webb, N. G., & Barrett, L. O. (2014). Student views of instructor-student rapport in the college classroom. *Journal of the Scholarship of Teaching and Learning*, *14*(2), 15–28.

Woods Jr, R. H. (2002). How much communication is enough in online courses?–exploring the relationship between frequency of instructor-initiated personal email and learners' perceptions of and participation in online learning. *International Journal of Instructional Media*, *29*(4), 377.

Xerri, M. J., Radford, K., & Shacklock, K. (2018). Student engagement in academic activities: A social support perspective. *Higher Education*, *75*(4), 589–605.

Xiu, Y., & Thompson, P. (2020). Effects of Video Discussion Posts on Social Presence and Course Satisfaction. *Electronic Journal of E-Learning*, *18*(5), 449–459.

Yasin, M., & Dzulkifli, M. A. (2011). Differences in depression, anxiety and stress between low-and high-achieving students. *Journal of Sustainability Science and Management*, *6*(1), 169–178.

Yukselturk, E., & Yildirim, Z. (2008). Investigation of interaction, online support, course structure and flexibility as the contributing factors to students' satisfaction in an online certificate program. *Journal of Educational Technology & Society*, *11*(4), 51–65.

APPENDIX A

INTERVIEW QUESTIONS ANALYZED

Thank you for agreeing to interview. My name is _____ and I am a biology education researcher and I study ways to improve the experiences of undergraduate science students. To our knowledge, nobody has explored how online learning can affect the experiences of undergraduate science students with depression and we feel this is an important area to further understand.

There are no right or wrong answers to any of these questions. I am going to ask you a series of questions, sometimes it might feel like you've already answered a question that I ask. That's OK. I have to ask all of the questions on my list, so just feel free to elaborate on your answer. Also, there may be times that I interrupt you and redirect you to a question. That's not because I'm not interested in what you have to say, but only because I have a short period of time with you and a lot of questions to ask.

Lastly, we acknowledge that COVID-19 has taken a toll on many people's mental health. However, we want to focus this study on the relationship between online learning and depression without considering COVID-19 challenges, so that our findings will be beneficial to people after COVID-19. The goal of this study is to interview students about their experiences with depression in online science courses, so my first question is, have you experienced depression while taking an online college science course?

In this interview we are going to ask you questions about how online science courses AFFECT YOUR DEPRESSION. Then, we are going to ask you about HOW YOUR DEPRESSION affects your ONLINE LEARNING IN SCIENCE. When I say online science courses, I'm talking about any learning of college science that you do online, for example a fully online science course.

We are going to start with how online science courses specifically affect your depression. We are going to start by asking you about how, if at all, some factors of online science learning affect your depression and then we will ask you if there is anything else that we haven't thought about that affects your depression in online science courses. With regard to how depression affects your online learning experience, I'm first going to ask you questions about how your online science courses negatively affect your depression and then I'm going to ask you about how your online science courses positively affect your depression.

I'm going to ask you about how specific aspects of your online science courses affect your depression.

Negatives

Have you ever **struggled to have your questions about course material answered** in online science courses?

> [If yes]: Talk to me about how, if at all, **struggling to get your questions about course material answered** in online science courses can make your depression worse.

Have you ever **struggled to make connections with other students** in online science courses?

[If yes]: Talk to me about how, if at all, **struggling to make connections with other students** in online science courses can make your depression worse.

Have you ever **struggled to make a connection with an instructor** in an online science course?

[If yes]: Talk to me about how, if at all, **struggling to make a connection with your instructor** in online science courses can make your depression worse.

Have you ever **experienced a lack of instructor to student communication** in online science courses?

[If yes]: Talk to me about how, if at all, the **lack of instructor student communication** in online science courses can make your depression worse.

In online science courses, you **do not need to show up to a class in person**.

Talk to me about how, if at all, the **lack of needing to show up to a class in person** in online science courses can affect your depression.

Have you ever felt like online science courses can be **fast-paced** in that you are asked to get a lot of work done in a short amount of time?

[If yes]: Talk to me about how, if at all, **the fast pace of online science courses** can affect your depression.

Feel free to take a minute to think about this next question: Is there anything else about online science courses that make your depression worse?

Positive

So now we are going to ask you about how aspects of online science courses may positively affect your depression.

Have you ever been able to **have your questions about course material answered** in online science courses?

[If yes]: Talk to me about how, if at all, **having your questions about course materia**l **answered** in online science courses can help you manage your depression?

Have you ever been able to **make connections with other students** in online science courses?

[If yes]: Talk to me about how, if at all, **connections with other students** in online science courses can help you manage your depression?

Have you ever been able to **make a connection with an instructor** in an online science course?

[If yes]: Talk to me about how, if at all, **making a connection with an instructor** in an online science course can help you manage your depression?

Have you experienced a **clear instructor to student communication** in online science courses?

[If yes]: Talk to me about how, if at all, the **clear instructor to student communication** in online science courses can help you manage your depression.

Have you experienced **flexibility to learn on your own time** in online science courses? By flexibility to learn on your own time, I'm talking about asynchronous classes where you do not have to show up online at a specific time.

[If yes]: Talk to me about how, if at all, the **flexibility to learn on your own time** in online science courses can help you manage your depression.

Have you ever felt a **sense of anonymity**, or like people in your class would not necessarily recognize you if they passed you on the street, in online science courses?

[If yes]: Talk to me about how, if at all, a **sense of anonymity** in online science courses can help you manage your depression.

Feel free to take a minute to think about this next question: Is there anything else about online science courses that helps you manage your depression?

Effect of depression on online learning

We've asked you a bunch about how your online learning experiences have impacted your depression. Now, we would like to switch gears and talk about how your depression has impacted your online learning.

I'm going to ask you some specific questions about how depression might affect your online learning in science.

Talk to me about how, if at all, your depression affects your **focus** when you are in an online science course.

Talk to me about how, if at all, your depression affects your **memory** when you are in an online science course.

Talk to me about how, if at all, your depression affects your **ability to communicate your thoughts** in the class when you are in an online science course.

Talk to me about how, if at all, your depression affects your **goal setting** for online science courses.

Talk to me about how, if at all, your depression affects your **time management** when you are in an online science course.

Talk to me about how, if at all, your depression affects the **effort you put in** when you are in an online science course.

Talk to me about how, if at all, your depression affects your **problem solving** when you are in an online science course.

Talk to me about how, if at all, your depression affects your **social interactions with other**

students when you are trying to learn online.

Feel free to take a minute to think about this next question: Are there any other ways in which you think depression affects your online science learning experience?

OK, that is all I have for you today. Is there anything else that you think would be helpful to tell me?

APPENDIX B

FULL DEMOGRAPHIC TABLE

Student-level demographics	**Interview participants % (n) (N = 24)**
Parent's highest level of education	
High School Diploma or GED	8.3 (2)
Some College but no degree	12.5 (3)
Associate degree (for example, AA, AS)	37.5 (9)
Bachelor's degree (for example, BA, AB, BS)	25.0 (6)
Master's degree (for example, MA, MS, MEng, MEd, MSW, MBA)	16.7 (4)
Member of LGBTQ+ community?	
Yes	50.0 (12)
No	50.0 (12)
Disability	
Yes	37.5 (9)
No	62.5 (15)
Struggled with Anxiety	
Yes	100.0 (24)
No	0 (0)
Native Language	

English	95.8 (23)
Decline to state	4.2 (1)
International Status	
Yes	0 (0)
No	100.0 (24)
Income Level	
Low Income (less than $25,000)	8.3 (2)
Middle Income ($25,000-$49,999)	79.2 (19)
High Income ($200,000 or higher)	4.2 (1)
Decline to state	8.3 (2)

APPENDIX C

HYPOTHESIZED NEGATIVE AND POSITIVE FACTORS THAT AFFECT DEPRESSION

Factors hypothesized to negatively affect depression

Factors	Citations
Struggling to have questions about course material answered	(Alawamleh et al., 2020; Boling et al., 2012)
Struggling to make connections with other students	(Alawamleh et al., 2020; Boling et al., 2012; Jurik et al., 2014)
Struggling to communicate or connect with an instructor	(Alawamleh et al., 2020; Aragon, 2003; Boling et al., 2012; Duta et al., 2015; Erichsen & Bolliger, 2011; Jurik et al., 2014; Kilgore, 2016; Muilenburg & Berge, 2005; Reese, 2015)
Not needing to show up to a class in person	(Muilenburg & Berge, 2005)
Fast pace of online courses	(Muilenburg & Berge, 2005; Tank, 2020)

Factors hypothesized to positively affect depression

Factors	Citations
Having questions about course material answered	(Alawamleh et al., 2020; Boling et al., 2012)
Making connections with other students	(Alawamleh et al., 2020; Boling et al., 2012; Croxton, 2014)
Communicating or making connections with an instructor	(Alawamleh et al., 2020; Aragon, 2003; Boling et al., 2012; Croxton, 2014; Duta et al., 2015; Erichsen & Bolliger, 2011; Kilgore, 2016; Nguyen, 2015)

Flexibility to learn on your own time	(Fedynich, 2013; Jaggars, 2014; Orr, 2019; Reese, 2015)
Feeling a sense of anonymity in online courses	(Fedynich, 2013; Jaggars, 2014)

APPENDIX D

CODING RUBRIC FOR HOW DEPRESSION AFFECTS COGNITIVE DOMAINS

Theme	Description	Percent
Effort (N = 24)		
Lack of motivation can affect effort	Student experience procrastination due to putting assignments to last minute and they don't understand or remember the full meaning.	75.00 (n = 18)
Critical of personal effort	Student describes that they question if they are doing enough or putting the optimal effort needed.	66.67 (n = 16)
Focus (N = 23)		
Loss of focus	Student describes that the nature of online education (e.g., pausing a video) makes it easier for them to allow themselves to lose focus for sustained periods of time.	82.60 (n = 19)
Lack of motivation	Student describes a lack of motivation when it is hard to focus in online courses, which could lead to negative self-talk or spiral.	47.83 (n = 11)
Overwhelmed /frustrated/distracted	Student describes they feel overwhelmed when they are not focused and are falling behind.	34.78 (n = 8)
Time management (N = 23)		
Procrastination	Student describes they feel like pushing everything to the last minute.	87.0 (n = 20)
Mental breakdown/depressive episode	Student describes that a mental breakdown or depressive episode can severely interfere with their ability to manage their time.	47.83 (n = 11)
Motivation	Student describes that depression can affect their motivation, which interferes with their ability to manage their time.	30.43 (n = 7)
Communicate thoughts (N = 23)		
Struggle to analyze information	Student describes that they cannot correctly analyze information or put their thoughts into words, which affects how they retain the module or causes them to write poorly on a discussion board.	47.83 (n = 11)

Fear of judgement	Student describes that they are discouraged to communicate because of fear of being judged, do not have confidence to communicate.	26.09 (n = 6)
Doesn't try	Student describes that they do not communicate about questions or anything generally.	21.74 (n = 5)
Enjoys written communication	Student describes that they like to communicate their thoughts non-verbally because they can edit.	21.74 (n = 5)
Goal setting (N = 20)		
No self-expectations/self-doubt	Student describes that they do not expect much for themselves in online courses and they try to just keep up with the bare minimum. Student also describes that they struggle with creating goals because of their own doubts on any potential self-expectations.	50.00 (n = 10)
Overwhelming	Student describes that they try to put all assignments into a calendar but over time that piles up and they are just staring at the computer for hours not doing anything, which puts their goals off.	40.00 (n = 8)
Lack of motivation	Student describes that they do not feel enough motivation to start studying in online courses.	25.00 (n = 5)
Problem solving (N = 20)		
Depression affects focus which affects problem solving	Student describes that if they are not focused, they are more likely to not problem solve, or it will be slowed down (foggy).	65.00 (n = 13)
Depression can make giving up easier	Student describes that they tend to be more tempted to give up when struggling to problem solve.	25.00 (n = 5)
Memory (N = 17)		
Dissociation	Student describes that they tend to disassociate, which affects how well they remember things and questions if they are mentally present to even remember.	94.12 (n = 16)

Energy and motivation	Student describes that they do not have the time, energy, and/or motivation to commit to memorize anything.	41.18 (n = 7)
Social interactions (N = 17)		
Depression makes social interactions exhausting	Student describes that it takes energy and is exhausting trying to connect with other students, or that it is not happening as easily as they would like.	76.47 (n = 13)
Depression causes bad mood	Student describes that when they are depressed, they are not a nice person and would not interact with anyone.	35.29 (n = 6)

APPENDIX E

CODING RUBRIC FOR NEGATIVE FACTOR THAT AFFECT DEPRESSION

Theme	Description	Percent
Fast pace of online courses (N = 24)		
Specific aspects of fast-paced courses that can exacerbate student depression		
Falling behind	Student describes that it is easy to fall behind in a fast-paced environment.	75.00 (n = 18)
Retaining info	Student describes the fast pace of online courses makes it difficult to retain any information.	33.33 (n = 8)
Lack of positive reinforcement	Student describes that due to the fast-paced nature in online courses, there seems to be a lack of reward or reinforcement for their accomplishments in the class because there is no time to do so, which exacerbates their depression.	12.50 (n = 3)
How fast-paced environment affects depressive symptoms		
Overwhelmed/ spiral	Student describes that the amount of information coming at them in a short period of time can cause them to feel overwhelmed or to spiral with negative thoughts.	83.33 (n = 20)
Hard/critical on themselves	Student describes that falling behind specifically can cause them to be critical of themselves.	58.33 (n = 14)
Fatigue, tired, no motivation	Student describes that the intensity and fast pace of online courses makes them more tired, fatigued, and less motivated.	41.67% (n = 10)
Not needing to show up to class in person (N = 16)		
Specific aspects of not showing up that can exacerbate student depression		
Lack of structure is challenging	Student describes that not showing up can cause a lack of structure or routine that can exacerbate depressive symptoms (e.g., no motivation to get	68.75 (n = 11)

	out of bed, to shower).	
Being alone/lack of interaction	Student describes that due to the online nature of their courses, they feel alone and isolated from the rest of the class because there is a lack of showing up to class in person. This causes them to not communicate or interact with others face-to-face, exacerbating their depression.	62.50 (n = 10)
Lack of positive reinforcement	Student describes that when you show up in class it can be helpful because you are more likely to receive positive reinforcement.	31.25 (n = 5)
How not showing up in class in person affects depressive symptoms		
Increases lack of motivation	Student describes hardship to find motivation and get out of bed since they don't have to physically be in a classroom, no routine, or lack of structure.	68.75 (n = 11)
Difficulty developing a relationship with other students (N = 20)		
Specific aspects of online education that make it difficult to connect with other students		
Harder to connect with people not face-to-face	Student describes that typing out social responses is difficult online. Student describes that they feel their opinions are shut down due to a difference in opinion when posting at a discussion board, which makes it discouraging to connect with other students.	70.00 (n = 14)
No time set aside for socializing	Student describes that they feel there is no venue and time to make friends or engage with students online.	35.00 (n = 7)
Forced social interaction	Student describes they don't like the "forced" interaction to engage.	15.00 (n = 3)

How struggling to connect with the students affects depressive symptoms		
Isolation	Student describes how not connecting with other students online can make them feel isolated. They can also describe how in-person connections make them feel like a part of a team (implying this is absent from online environments).	70.00 (n = 14)
Personal low self-image (dumb, bad, worthless)	Student describes that they feel worthless if they reach out to others in class and it is not reciprocated.	40.00 (n = 8)
Spiraling/overwhelmed	Student describes that not being able to connect with other students causes them to feel overwhelmed or lost, which ends up making the student spiral emotionally.	30.00 (n = 6)
Difficulty communicating or developing a relationship with the instructor (N = 19)		
Specific aspects of online education that make it difficult for students to connect or communicate with instructors		
Lack of support	Student describes that they don't have instructor support online and some instructors provide minimal effort when student tries to connect.	84.21 (n = 16)
Lack of positive reinforcement/lack of feedback	Student describes that having a lack of positive reinforcement or lack of positive reaffirmation can exacerbate their depressive symptoms. Student describes that it was anxiety inducing that the professor would communicate late or share an announcement after something was due, so responding late or not responding at all was overwhelming.	78.94 (n = 15)
How struggling to connect or communicate with the instructor affects depressive symptoms		

Assumption that the instructor views them negatively	Students describes that if they are unable to connect with instructors (e.g., if an instructor does not reply to them) then they are viewed by the instructor as not capable or not meeting their expectations.	73.68 (n = 14)
Personal low self-image (dumb, bad, worthless)	Student describes that when they try to connect with an instructor and the instructor does not make the effort to personally reply it came make them feel "dumb," "bad," or "worthless."	47.37 (n = 9)
Emotional distress/spiral	Student describes that when they struggle to communicate with the instructor it can cause them to feel increasingly frustrated or irritable. Student describes that due to a lack of communication, they feel that there is no one they can go to, or in other words defeated.	47.37 (n = 9)
Lack of motivation/giving up	Student describes that a lack of communication with the instructor can cause them to feel hopeless, like they should give up, or unmotivated.	36.84 (n = 7)
Assumption that the instructor views them negatively (FNE)	Student describes that a lack of student/instructor communication makes them feel as if the instructor views them in a negative way such as the student is a burden or various other negative factors.	26.31 (n = 5)
Difficulty having questions answered (N = 18)		
Specific aspects of online education that make it difficult for students to have questions answered		
Questions can be misunderstood	Student describes that their questions are not understood due to language barriers, in-text communication issues, lack of accommodations, or anything else that the student feels makes it harder to get their question across in an online format.	61.11 (n = 11)

Difficult to get questions answered on time	Student describes that it is difficult for their depression if they cannot get questions answered on time. Student describes they do not feel in control of the learning pace due to the time they spent receiving an answer from the professor and sometimes not even receiving a response back.	33.33 (n = 6)
Online can be more public or intimidating (FNE)	Student describes that asking a question online can be more public. As such they are embarrassed or struggle to ask questions in front of the class or in groups because of fear of negative evaluation.	16.67 (n = 3)
How struggling to get questions answered affects depressive symptoms		
Low self-image/feeling stupid	Student describes that not getting their questions answered can cause them to feel negatively about themselves, specifically they feel stupid. This can be because they do not understand something or because they did not phrase a question correctly.	88.89 (n = 16)
Causes spiraling	Student describes that not having a question answered can cause them to spiral. For example, student describes how not getting a question answered can lead to thoughts about having trouble with the assignment, then the course, then being stupid, then never doing anything. In short, this can cause a small concern to lead to an array of depressive thoughts.	33.33 (n = 6)
Creates a feeling of helplessness/ hopelessness/defeat	Student describes that not being able to get questions answered can cause a feeling of helplessness, hopelessness, or defeat (often we see the pattern that not getting a question answered can lead to confusion which results in these more negative feelings).	27.78 (n = 5)

Self-paced nature of online courses (N = 11)		
Specific aspects of self-paced courses that can cause exacerbate student depression		
Due dates	Student describes that a lack of structure can exacerbate their depression because it is hard to be self-controlled and this can lead to a depression spiral.	100.00 (n = 11)
Doubt about preparedness	Student describes that they doubt online courses prepare them well enough and then doubt their ability as a scientist.	27.27 (n = 3)

APPENDIX F

CODING RUBRIC FOR POSITIVE FACTOR THAT AFFECT DEPRESSION

Theme	Description	Percent
Flexibility to learn on your own time (N = 24)		
Specific aspects of flexibility that leads to a positive impact on depression		
Allows for navigating depressive symptoms	Student describes that having flexibility helps when they don't have the energy or motivation for coursework or the mental stamina. Flexibility allows students to recover (e.g., stay in bed, break down and cry) and this is posed as a good thing.	75.00 (n = 18)
Workload/work-life balance	Student describes that having the flexibility to learn on their own time allowed them to work full-time and survive school and life (e.g., family events, therapy).	58.33 (n = 14)
Feeling of control	Student describes that the flexibility to learn on their own time is helpful for their depression because it provides a feeling of control over their life.	41.67 (n = 10)
Productive	Student describes they feel more productive because of the flexibility of online courses.	37.50 (n = 9)
How flexibility affects depressive symptoms		
Manageable/comfortable/stress reducing	Student describes that the flexibility to work at their own pace and manage their own schedule allowed them not only to learn, but to be comfortable with how they are learning.	91.67 (n = 22)
Student able to clearly communicate or develop a relationship with the instructor (N = 24)		
Specific aspect of communicating/connecting with the instructor-students affects depressive symptoms		
Time management/structure	Student describes they have better time management in online course when instructions are clear. Student may also describe this as work-life balance. Student may also describe that they feel a sense of structure and are able to plan their time better.	62.50 (n = 15)
Helps clear things	Student describes that getting help from instructors might rationalize things instead of	45.83 (n = 11)

up/positive reinforcement	exaggerating issues.	
Affirming/validating	Student describes that when they are able to successfully communicate with the instructor, they feel important, validated, or affirmed.	41.67 (n = 10)
Productive	Student describes that they feel productive when they have everything they need and they actually look forward to doing the work when they make a connection with their instructor.	25.00 (n = 6)
More motivated	Student describes that when they successfully communicate with the instructor, they are more motivated to learn or complete work.	25.00 (n = 6)
Avoids shutting down	Student describes when they successfully communicate with the instructor it helps them avoid shying away or shutting down.	12.50 (n = 3)
How communicating/connecting with the instructor students affects depressive symptoms (N = 20)		
Support	Student describes that making connections with the instructor makes them feel supported, like they have someone they can go to if they have a question or if they're struggling. Student describes that when reaching out to the instructor about something not working, the instructor would explain that it was ok and that other students are also having the same problem and sent out an announcement instead of missing the material.	70.83 (n = 17)
Not feeling alone/isolated	Student describes that making connections with the instructor or simply having an instructor that cares about the course can help them feel less isolated or alone.	54.17 (n = 13)
Ease having questions answered (N = 22)		
Specific aspects of having questions answered that can lead to a positive impact on depression		
Control	Student describes that they feel in control and not overwhelmed when their questions are answered.	45.45 (n = 10)

Relief	Student describes that they feel relieved and calm when their questions are answered.	36.36 (n = 8)
How having questions answered affects depressive symptoms		
Stops spiral/pressure	Student describes that having their questions answered can stop a spiral of negative thoughts.	54.55 (n = 12)
Be a light/support	Student describes that having their questions answered can serve as a "light" or source of support when they are in a dark place.	40.91 (n = 9)
Motivated	Student describes that they feel more motivated and less tired when a TA or professor is helping and that they are not alone.	40.91 (n = 9)
Less isolated	Student describes that they feel less isolated when someone might have the same question as them.	31.82 (n = 7)
Anonymity (N = 20)		
Specific aspects of how anonymity affects depressive symptoms		
Do not have fear of negative evaluation	Student describes how the anonymity of online education means that they do not spend time worrying about how others will evaluate them. Particularly, they do not have to worry about whether people will judge their questions or opinions. This includes if a student mentions they do not need to be people pleasing.	95.00 (n = 19)
Comfortable	Student describes that they prefer to be anonymous because they are more of an introvert, they are working alone, live alone, or it is more comfortable.	45.00 (n = 9)
Less responsible for shared work	Student describes they feel capable not relying on other students and in control of their own grade.	15.79 (n = 3)
Manageable	Students describes working with students makes the work more manageable.	15.79 (n = 3)
Developing a relationship with other students (N = 19)		

Specific aspects of connecting with other students that leads to a positive impact on depression		
Helps to know other people are going through the same things	Student describes that knowing there are other people with similar questions or other people going through similar material helps their depression.	84.20 (n = 16)
Accountability	Student describes feeling that they are held accountable when they can connect with others online.	31.58 (n = 6)
Better able to engage in the course	Student describes that they are better able to engage in the course if they are able to engage with other students.	31.58 (n = 6)
How making connections with other students affects depressive symptoms		
Relieves isolation/increases motivation	Student describes feeling less isolated when they are able to connect with other students.	78.95 (n = 15)
More joyful	Student describes that when they make a connection with other students it is enjoyable to have someone to look for in their asynchronous online courses and it made them feel prepared because they know who they are going to be working with.	10.53 (n = 2)

APPENDIX G

REFERENCES

Alawamleh, M., Al-Twait, L. M., & Al-Saht, G. R. (2020). The effect of online learning on communication between instructors and students during Covid-19 pandemic. *Asian Education and Development Studies*.

Aragon, S. R. (2003). Creating social presence in online environments. *New Directions for Adult and Continuing Education*, *2003*(100), 57–68.

Boling, E. C., Hough, M., Krinsky, H., Saleem, H., & Stevens, M. (2012). Cutting the distance in distance education: Perspectives on what promotes positive, online learning experiences. *The Internet and Higher Education*, *15*(2), 118–126.

Croxton, R. A. (2014). The role of interactivity in student satisfaction and persistence in online learning. *Journal of Online Learning and Teaching*, *10*(2), 314.

Duta, N., Panisoara, G., & Panisoara, I.-O. (2015). The Effective Communication in Teaching. Diagnostic study regarding the academic learning motivation to students. *Procedia-Social and Behavioral Sciences*, *186*, 1007–1012.

Erichsen, E. A., & Bolliger, D. U. (2011). Towards understanding international graduate student isolation in traditional and online environments. *Educational Technology Research and Development*, *59*(3), 309–326.

Fedynich, L. V. (2013). Teaching beyond the classroom walls: The pros and cons of cyber learning. *Journal of Instructional Pedagogies*, *13*.

Jaggars, S. S. (2014). Choosing between online and face-to-face courses: Community college student voices. *American Journal of Distance Education*, *28*(1), 27–38.

Jurik, V., Gröschner, A., & Seidel, T. (2014). Predicting students' cognitive learning activity and intrinsic learning motivation: How powerful are teacher statements, student profiles, and gender? *Learning and Individual Differences*, *32*, 132–139.

Kilgore, W. (2016). Let's talk: Effectively Communicating with your Online Students. *Humanizing Online Teaching and Learning*.

Muilenburg, L. Y., & Berge, Z. L. (2005). Student barriers to online learning: A factor analytic study. *Distance Education*, *26*(1), 29–48.

Nguyen, T. (2015). The effectiveness of online learning: Beyond no significant difference and future horizons. *MERLOT Journal of Online Learning and Teaching*, *11*(2), 309–319.

Orr, T. (2019). *Women with depression in online learning: A descriptive phenomenological analysis*.

Reese, S. A. (2015). Online learning environments in higher education: Connectivism vs. dissociation. *Education and Information Technologies*, *20*(3), 579–588.

Tank, P. (2020). *Technical issues, pandemic trauma, lack of motivation, time management skills: Students suffer throu- Edexlive*. https://www.edexlive.com/news/2020/aug/25/technical-issues-pandemic-trauma--time-management-students-suffer-through-online-classes-141

APPENDIX H
IRB APPROVAL

EXAMINING HOW ONLINE BIOLOGY LEARNING ENVIRONMENTS AFFECT STUDENT DEPRESSION

APPROVAL: EXPEDITED REVIEW

Katelyn Cooper
CLAS-NS: Life Sciences, School of (SOLS)
-
Katelyn.Cooper@asu.edu

Dear Katelyn Cooper:

On 11/13/2020 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	How studying biology in online environments affects students with anxiety and depression?
Investigator:	Katelyn Cooper
IRB ID:	STUDY00012862
Category of review:	
Funding:	Name: Howard Hughes Medical Institute (HHMI),Grant Office ID: FP00013045
Grant Title:	FP00013045;
Grant ID:	FP00013045;
Documents Reviewed:	ï Demographic survey from STUDY00011484, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); ï Example recruitment email, Category: Recruitment Materials; ï Funding Source, Category: Sponsor Attachment; ï interview consent form, Category: Consent Form; ï IRB, Category: IRB Protocol; ï Logan CITI, Category: Other; ï Reminder email, Category: Recruitment Materials; ï Sample Participant interview questions , Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); ï sample survery questions , Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

The IRB approved the protocol from 11/13/2020 to 11/12/2022 inclusive. Three weeks before 11/12/2022 you are to submit a completed Continuing Review application and required attachments to request continuing approval or closure.

If continuing review approval is not granted before the expiration date of 11/12/2022 approval of this protocol expires on that date. When consent is appropriate, you must use final, watermarked versions available under the "Documents" tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc: Tasneem Mohammed
Tasneem Mohammed
Katelyn Cooper
Logan Gin