

The Aspects of Active-Learning Science Courses That Exacerbate and Alleviate Depression in Undergraduates

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ABSTRACT

College science courses continue to transition from traditional lecture to active learning, which has been shown to have both alleviating and exacerbating effects on undergraduate mental health. Notably, existing studies have primarily examined the relationship between active learning and anxiety, and no studies have specifically assessed the relationship between active learning and depression. To address this gap, we conducted hourlong exploratory interviews with 29 undergraduates from six institutions who identify as having depression and who had been enrolled in at least one active-learning college science course. We probed how undergraduates' depression affects their experiences in active learning, and in turn, what aspects of active-learning practices exacerbate or alleviate students' depressive symptoms. Students described that their depression negatively impacted their cognitive domains, which could make learning and social interactions challenging. Additionally, we found that the underlying aspects of active-learning practices that impact students' depression fall into four overarching categories: opportunities to compare oneself with others, socializing with others while learning, frequent formative evaluation, and engagement in learning. Each of these aspects of active learning could alleviate and/or exacerbate depressive symptoms. This work supports recommendations to create more inclusive active-learning courses for students with depression.

INTRODUCTION

In 2019, a nationwide survey revealed that 39.0% of undergraduates met the clinical criteria for major depressive disorder, and that percentage increased to 45.7% during the COVID-19 pandemic (Kim *et al.*, 2022). The proportion of undergraduates in the sciences who struggle with depression is likely even higher, with a recent study finding that more than 50% of science majors identify as having depression (Busch *et al.*, 2022). Given the ubiquity of depression, defined as a mood disorder that results in persistent feelings of sadness and hopelessness (American Psychiatric Association, 2013), the scientific community has begun to recognize the importance of bolstering undergraduate mental health (Leshner, 2021). While universities have primarily responded to the rising rates of mental illness among college students by increasing access to mental health support such as counseling (National Council on Disability, 2017), adapting undergraduate learning environments to be more inclusive of students struggling with depression may be a complementary approach to promoting undergraduate mental health (Busch *et al.*, 2022).

The rigor, competitive nature, and chilly environment of science courses likely challenge student mental health (Everson *et al.*, 1993; Strenta *et al.*, 1994; Seymour and Hunter, 2019). Additionally, aspects of science learning environments can affect undergraduate depression specifically. For example, an interview study of 35 undergraduate researchers with depression found that experiencing failure, unreasonable expectations, and harsh criticism can exacerbate undergraduates' depressive

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symptoms, while structured research experiences and positive social relationships can help alleviate depression (Cooper *et al.*, 2020a). Further, the transition to online learning during the COVID-19 pandemic spurred investigations of the relationship between learning science online and depression. An interview study of 24 undergraduates with depression taking online science courses revealed that difficulty developing relationships with other students online often exacerbated students' depressive symptoms, while the flexibility of completing course work when and where students wanted, the ease of having questions answered, and developing relationships with instructors helped lessen depressive symptoms (Mohammed *et al.*, 2022). Researchers built on this study by examining whether these aspects of online learning affected student depression at scale (Busch *et al.*, 2022). A survey study of more than 1100 undergraduate students with depression taking online science courses identified difficulty getting to know other students in class and online monitored proctored testing as exacerbating depression. Conversely, the flexibility of doing course work when and where students wanted was the most frequently reported aspect of online learning that alleviated students' depressive symptoms.

An emerging science learning environment that has yet to be explored in relation to undergraduate depression is active learning. In active-learning courses, undergraduates engage in their learning through activities and discussions in class (Freeman *et al.*, 2014). National calls continue to champion the transition of science courses from traditional lecture to active learning, because on average students learn more and fail less in active learning (President's Council of Advisors on Science and Technology, 2012; Freeman *et al.*, 2014; American Association for the Advancement of Science, 2015; Theobald *et al.*, 2020). Additionally, active learning has been celebrated as an inclusive teaching practice (Dewsbury and Brame, 2019) due to its disproportionately positive impact on the performance of students who identify as women (Lorenzo *et al.*, 2006), persons excluded because of their ethnicity or race (Eddy and Hogan, 2014; Theobald *et al.*, 2020), first-generation college-going students (Eddy and Hogan, 2014), and students who come from educationally or economically disadvantaged backgrounds (Haak *et al.*, 2011; Theobald *et al.*, 2020). However, there has been increased concern about whether active learning is inclusive of students with mental health conditions (Cooper and Brownell, 2020; Hsu and Goldsmith, 2021; Yannier *et al.*, 2021). Notably, studies examining the relationship between active learning and mental health have focused exclusively on anxiety (England *et al.*, 2017; Cooper *et al.*, 2018a; Cooper and Brownell, 2020; Brigati *et al.*, 2020; Downing *et al.*, 2020; Adkins-Jablonsky *et al.*, 2021; Baepler, 2021; Hood *et al.*, 2021), presumably because it is the most common mental health concern among college students (Center for Collegiate Mental Health, 2021). Anxiety and depression are highly comorbid and intertwined (Kalin, 2020). They share underlying physiological processes (Boyer, 2000; Clark and Beck, 2010; McTeague *et al.*, 2020) and can manifest similarly, including feelings of agitation and restlessness (Kreitler, 2018). However, there are unique differences between the two conditions. Depression is distinct from anxiety, because it includes symptoms of anhedonia, defined as the decreased ability to feel pleasure, as well as a lack of positive affect, while anxiety is charac-

terized by the presence of somatic symptoms of hyperarousal (Clark and Watson, 1991). Therefore, it is recommended that anxiety and depression be viewed theoretically and practically as distinct (Kreitler, 2018).

The extant research highlights that active learning can both alleviate and exacerbate anxiety (Cooper *et al.*, 2018a; Downing *et al.*, 2020). Over the past 5 years, researchers' perceptions of the relationship between active learning and mental health have changed. Some of the first studies focused primarily on which active-learning practices (e.g., clicker questions, group work) evoked student anxiety (England *et al.*, 2017; Cooper *et al.*, 2018a; Downing *et al.*, 2020), while researchers later proposed that active-learning practices do not have a unidirectional effect on anxiety (Downing *et al.*, 2020). Instead, how active-learning practices are implemented (e.g., associated course points, timing, whether students work with others) affects how students' mental health is impacted. Specifically, the increased social interactions among students can worsen student anxiety, primarily because of fear of negative evaluation (Cooper *et al.*, 2018a), defined as the sense of dread students experience when they perceive they are being evaluated by others in a social situation (Watson and Friend, 1969; Weeks *et al.*, 2005). Fear of negative evaluation is often exacerbated when students are asked to work with others with whom they have not developed relationships. However, engaging in social situations and realizing that others also struggle with difficult concepts can lessen students' anxiety in active learning (Cooper *et al.*, 2018a; Downing *et al.*, 2020). As such, the social nature of active learning does not appear to have an exclusively negative or positive impact on undergraduate mental health. Students describe that solving problems on worksheets and answering clicker questions can provide them feedback about what they do and do not know, lessening their anxiety as they approach exams (Cooper *et al.*, 2018a; Downing *et al.*, 2020; Adkins-Jablonsky *et al.*, 2021), whereas engaging in formative assessments and losing points when they do not understand a topic can exacerbate their anxiety (Cooper *et al.*, 2018a; Downing *et al.*, 2020). These findings have informed multiple recommendations about how to be inclusive of students with anxiety while continuing to teach in an active-learning way (Brame, 2019; Cooper *et al.*, 2021; Hsu and Goldsmith, 2021; Yannier *et al.*, 2021). However, there has been no research examining how active learning affects other common mental health conditions, including depression. While depression is a distinct condition from anxiety, it is often comorbid and shares many symptoms with anxiety (Clark and Watson, 1991; Kreitler, 2018; Kalin, 2020); as such, we hypothesize that some, but not all, aspects of active learning that exacerbate and alleviate anxiety also affect depression.

In addition to understanding how active learning affects depression, it is important to understand how depression affects undergraduates' experiences in active-learning courses. Prior studies, which likely gathered data from traditional lecture courses with minimal student engagement, found that depression is commonly associated with decreased academic performance (Hysenbegasi *et al.*, 2005; DeRoma *et al.*, 2009). However, students with depression may also struggle in learning environments that require more engagement. For example, undergraduates engaging in research report that depression decreases their motivation, productivity, and concentration (Cooper *et al.*, 2020a), and undergraduates taking online

courses highlight that depression negatively impacts an array of cognitive domains, such as their effort, focus, and time management (Mohammed *et al.*, 2022). We hypothesize that such cognitive domains would also be impacted in the context of active learning, especially considering the increased participation in activities and discussions that is associated with these courses.

To characterize the relationship between active learning and undergraduate depression, we conducted a national exploratory interview study of 29 undergraduates who identify as having depression and who have been enrolled in at least one in-person active-learning college science course. Our research questions were:

1. How, if at all, does depression affect undergraduates' experiences in college science active-learning courses?
2. What aspects of college science active-learning courses exacerbate undergraduate depressive symptoms?
3. What aspects of college science active-learning courses alleviate undergraduate depressive symptoms?

METHODS

This study was approved by the Institutional Review Board at Arizona State University (IRB no. 00014817).

Development and Validation of the Interview Script

We developed an interview script to probe how active learning impacts undergraduate depression. After drafting the initial interview script, one researcher (T.A.) conducted five think-aloud interviews with individuals who identified as having depression and have taken an in-person active-learning college science course in order to establish cognitive validity of the questions (Trenor *et al.*, 2011). After each think-aloud interview, the script was iteratively revised until all interview questions were interpreted as intended. A final copy of the interview script can be found in the Supplemental Material.

In the interviews, we aimed to identify underlying aspects of active-learning practices, as opposed to the practices themselves, that may alleviate or exacerbate student depression. For example, we hypothesize, based on prior work examining active learning and anxiety (Cooper *et al.*, 2018a; Downing *et al.*, 2020), that a single active-learning practice, such as group work, is too complex to have a unidirectional effect on depression. Instead, we hypothesized that underlying aspects of group work, such as the social aspect, would have a more specific impact on depression. For example, the social aspect of group work may exacerbate students' depression due to fear of judgment from others, or it may alleviate students' depression by providing a sense of camaraderie among group members (Cooper *et al.*, 2018a; Downing *et al.*, 2020). In prior studies we have found that students often had not thought about the relationship between their learning and mental health (Cooper *et al.*, 2018a; Downing *et al.*, 2020). As such, we have found it most effective to ask students about how specific active-learning practices affect their mental health, which generally elicits the underlying aspects contributing to the alleviation or exacerbation of symptoms. Therefore, we first asked what aspects of science active-learning courses, if any, worsen their depression. We then asked if there were any aspects of science active-learning courses that decrease their feelings associated with depression. After, we probed whether students had ever engaged in three common active-learning

practices: group work, defined for students as working with at least one other student in class; clicker questions, defined for students as answering questions posed by the instructor using an electronic device; and cold calling, defined for students as being asked to speak out in front of the whole class without volunteering to do so. For each practice that a student had participated in, we asked them to explain how, if at all, the practice worsened and decreased their depressive symptoms. Next, we asked students how their depression impacts the process of learning content and their social interactions specifically in the context of active-learning college science courses.

Development of the Post Survey

After the interview, students completed a short survey that included demographic questions, questions about their college experiences, and questions about their depression. Specifically, students were asked to report the average severity of their depression during their time in active-learning college science courses, whether their depression had been formally diagnosed, and how they were managing their depression. The post-interview survey can be found in the Supplemental Material.

Recruitment and Interviews

In Fall of 2021, we sent an email to the national Listserv for the Society for the Advancement of Biology Education Research (SABER) asking instructors who teach science courses in active-learning ways to help recruit students in their classes for our study exploring the relationship between active learning and depression. We chose to recruit through the SABER Listserv because we wanted to maximize the number of instructors we would reach who teach in active-learning ways, and the SABER community is generally committed to using evidence-based teaching practices (Offerdahl *et al.*, 2011). The recruitment script that we asked instructors to send to undergraduates in their active-learning science courses invited students who identify as having depression to participate in a 30–60 minute interview about their experiences in active-learning college science courses in exchange for a \$15 gift card. We did not require a formal diagnosis of depression from the students who participated in the interviews because we know that mental health care is disproportionately unavailable to individuals who identify as Latin* and Black and individuals who come from low-socioeconomic backgrounds (Howell and McFeeters, 2008; Kataoka *et al.*, 2011; Santiago, 2013). Additionally, self-reported depression is considered to be fairly accurate and appropriate in nonclinical contexts (Arias-de la Torre *et al.*, 2020).

Fifty-two students agreed to be interviewed. However, 27 (52%) of those students missed their initial interviews. Students who missed their interviews were given an opportunity to sign up for another interview time; eight students rescheduled and showed up for the second opportunity. Our research group has found that no-show rates are particularly high when interviewing students with depression; it is common for ~50% of students to not attend their initial interviews (Cooper *et al.*, 2020a; Gin *et al.*, 2021). Four interviews ended early due to the participant not meeting the criteria for the interview (e.g., not having depression or not having been enrolled in an active-learning college science course) or because of technology issues that prevented the interview from being completed. A total of 29 student interviews were analyzed for this study.

Data saturation was reached within the first 24 interviews, meaning there were no new significant themes that emerged (Guest *et al.*, 2006); therefore, the research team did not recruit any additional participants for this study. All interviews were conducted by one researcher (T.A.) over Zoom and ranged from 30 to 60 minutes. Each interview was audio-recorded and transcribed.

Analysis of Interviews

Three researchers (T.A., C.A.B., K.M.C.) used inductive coding (Fereday and Muir-Cochrane, 2006) to independently review a randomly selected set of eight interview transcripts and took analytic notes on emerging codes. The researchers compared their notes and articulated a set of common codes coming out of the interviews (Glesne, 2016). These codes included ways that depression affected students' experiences in active learning, as well as aspects of active learning that alleviated and exacerbated students' depression. Notably, the interview questions regarding active-learning practices were considered in aggregate to identify the underlying aspects of active-learning practices that affect student depression, and we did not identify codes unique to each of the three active-learning practices. Each coder then reviewed a different randomly selected set of eight interviews to test the codebook. The codebook was edited a final time, and then two researchers (T.A. and C.A.B) independently coded the same randomly selected set of eight interviews (28% of all interviews) and compared their codes. Their Cohen's kappa interrater score was 0.94 (Landis and Koch, 1977). One researcher (T.A.) coded the remaining 21 interviews. A final copy of the rubric can be found in the Supplemental Material.

Reporting of Results

In the *Results and Discussion*, we report ways that depression impacts students' experiences in active learning and aspects of active learning that either alleviate or exacerbate depressive symptoms that were reported by 20% of the interview participants. However, all aspects of active learning that affect depression that were mentioned by participants are included in the codebook in the Supplemental Material. While we report the percentage of students who described each aspect in their interviews, we caution that such percentages can lead to inaccurate conclusions about the generalizability of the results to a broader population (Maxwell, 2010). The qualitative data obtained from the interviews are used to better understand students' experiences with depression in undergraduate science courses that implement active learning, rather than to make claims about the prevalence of these experiences (Glesne and Peshkin, 1992). Quotes from students were lightly edited for clarity using ellipses to indicate text that was excluded and adding clarification brackets. Each student was given a pseudonym for anonymity.

Positionality Statement

Some of the authors identify as having depression and some do not. At the time of the study, one author was an undergraduate (T.A.) who had taken active-learning biology courses. Two of the authors (C.A.B. and K.M.C.) had taught biology courses in an active-learning way.

RESULTS AND DISCUSSION

We present the *Results and Discussion* together to contextualize our findings within the prior literature and then follow this section with a brief *General Discussion*. We chose to present the ways in which depression impacts students' experiences in active learning in a table for brevity and because we felt as though student quotes were sufficient and did not require additional context to be interpreted. Conversely, we chose to present student quotes describing the underlying aspects of active learning that alleviate and exacerbate student depression in the text, because the complexity of students' experiences often warranted additional elaboration.

Participants and the Relationship between Anxiety and Depression

Participants in this study were primarily women, Asian, and continuing-generation college students. Students came from varied socioeconomic backgrounds and were commonly in their first, second, or third year of college. All students interviewed had taken at least one in-person active-learning college science course, defined as a course in which students are engaged in activities such as group work, clicker questions, and/or discussions in class, in contrast to traditional lecture courses, in which the instructor just lectures and students just listen. More than 80% of students reported having at least moderate depression during the time they were enrolled in college science active-learning courses. Most students had been diagnosed with and were being treated for depression. Student, academic, and depression demographics are reported in Table 1.

Notably, every participant in the study also identified as having anxiety, and we asked students to identify any link between their depression and anxiety. Students commonly described their depression preceding anxiety or their anxiety preceding depression—both of which align with literature suggesting that these conditions share similar physiological processes. Given the intertwined nature of anxiety and depression (Kalin, 2020), we did not attempt to disentangle whether students' responses about their depression were in part related to their anxiety, because we expected they would be. We highlight particular aspects of the interview when students explicitly discussed anxiety as it related to their depression.

Students Report That Their Depression Has an Exclusively Negative Impact on Their Experiences in Active Learning

We asked students how their depression impacts the process of learning content and their social interactions in active-learning college science courses. In response to these questions, students described that depression made it difficult to engage in social interactions (90%). Additionally, students explained that depression decreased their energy (69%), focus (66%), motivation (38%), memory (24%), and patience (21%), while also causing them to doubt their intelligence (41%; Table 2). These findings align with a previous study highlighting that depression can impact cognitive domains such as attention, communication skills, executive function, problem solving, and social interactions (Grabinger *et al.*, 2008). Further, undergraduates perceive that when depression affects their cognitive domains it can impact their performance in online science courses (Mohammed *et al.*, 2022) and undergraduate

TABLE 1. Student, academic, and depression demographics for all interview participants ($n = 29$)

Student-level demographics	% (n)	Academic demographics	% (n)	Depression demographics	% (n)
Gender identity		In-person college science classes completed		Clinical diagnosis	
Man	6.9 (2)	1–2	44.8 (13)	Yes	69.0 (19)
Woman	79.3 (23)	3–4	13.8 (4)	No	27.6 (8)
Nonbinary	13.8 (4)	5–6	20.7 (6)	Declined to state	6.9 (2)
		7 or more	20.7 (6)		
Race/ethnicity		In-person active-learning college science courses completed		Being treated for depression	
Asian or Asian American	41.2 (12)	1–2	72.4 (21)	Yes	72.4 (21)
Black or African American	6.9 (2)	3–4	24.1 (7)	No	20.7 (6)
Hispanic, Latin*, or Spanish origin	27.6 (8)	5–6	0.0 (0)	Declined to state	6.9 (2)
White	17.2 (5)	7 or more	3.4 (1)		
More than one race/ethnicity	3.4 (1)			Severity of depression	
Declined to state	3.4 (1)			Mild	17.2 (5)
				Moderate	51.7 (15)
College-generation status				Severe	31.0 (9)
First generation	31.0 (9)				
Continuing generation	58.6 (17)				
Declined to state	10.3 (3)				
Year in college					
First year	27.6 (8)				
Second year	27.6 (8)				
Third year	37.9 (11)				
Fourth year or later	6.9 (2)				
Anxiety					
Yes	100.0 (29)				
No	0.0 (0)				

research experiences (Cooper *et al.*, 2020a). Therefore, it is imperative that on-campus disability resource centers recognize the evolution of traditional lecture courses and identify appropriate and effective accommodations for students with depression in active-learning environments (Gin *et al.*, 2020).

Aspects of Active Learning That Exacerbate and Alleviate Depressive Symptoms in Undergraduates

We identified four overarching aspects of active learning that impact students' depressive symptoms. These overarching aspects emerged across all active-learning practices probed during the interviews. We describe specifically how each of these aspects of active learning can both exacerbate and alleviate depressive symptoms.

Opportunities to Compare Self with Others. Students commonly described that active-learning science courses provide frequent opportunities to compare themselves with others. These opportunities can occur during a social engagement, such as during group work, or a non-social engagement, such as when students assess how their answer to a clicker question compares with overall class performance.

Feeling Inferior Compared with Peers Can Exacerbate Depressive Symptoms (75.9%). Students highlighted that their depression could be exacerbated when they compare themselves with their peers in class who appeared to understand science concepts

more quickly or more in-depth than they do. This was particularly true for individuals who make global attributions. Global attributions involve perceiving that a relatively specific event impacts larger aspects of their lives and are known to further exacerbate depressive symptoms (Abramson *et al.*, 1989). For example, a student may interpret not getting a question right that others answered correctly as evidence that the student should not be enrolled in the class or does not belong in the major. One student, Randall, described that, when comparing himself with others in active learning, he sometimes questions whether he belongs as a science major.

Randall: "I think one way that [active learning] has been bad [for my depression] was the feeling of competition. (...) If I see students do really well [in active learning] and I feel I didn't do well at all, that will make me doubt myself and whether I'm actually at the right progress in my class, or whether I should just change my field of study."

Relatedly, Jennifer described a depressive spiral wherein feeling as though she was the only one not understanding the content made her feel hopeless about her future.

Jennifer: "[Group work can worsen my insecurity, and] relating to the topic of security, it mostly makes me think about my future and that makes me think that everyone else is going to have a good future because they're able to grasp the

TABLE 2. Ways in which depression affects students' experiences in active learning and example quotes

Depression affects experience in active learning	% (n) (N = 29)	Example quote 1	Example quote 2
Difficulty engaging in social interactions	89.7 (26)	Lisa: “[Before I had depression], it was so easy to talk to people randomly, even just waiting for the professor, but now I don’t really want to say anything. I have to force myself to do it. (...) It’s very hard to just make conversation.”	Jeremy: “Participating, that’s a huge drain on my social battery and it makes it harder for me to interact with other people. (...) It’s a lot more mentally taxing trying to socialize with other people in the group when you’re already so worried about your own academic performance and showing up to class.”
Energy	69.0 (20)	Nora: “[When you have a depressive episode] you don’t want to do anything, and you just don’t have the energy to exert. You’re just in survival mode. I weigh the options like, ‘Oh, is it even worth going? I’m not going to learn anything. I’m not good enough for this.’”	Taylor: “Some days if I’m low energy from having depressive thoughts, I just won’t feel like interacting as much or engaging as much in the class.”
Focus	65.5 (19)	Taylor: “Having certain depressive thoughts will distract me from the class, and I won’t be as engaged doing clicker questions or listening to the lecture itself.”	Danielle: “I tend to get super spacey when I’m having one of the bigger depressive episodes. It definitely makes it harder to actually focus. And I’ll admit that I’ve gone to a lecture and just not really paid attention and just clicked random buttons to get the credit because I can’t do more than that.”
Increases self-doubt about intelligence	41.4 (12)	Christina: “My depression is like a negative voice in my head invalidating everything. If I want to ask a question, it’s like that little voice is telling me, ‘No, you’re going to sound dumb.’ And that hurts me, because I’m not able to expand on what my question is and tie it to what I’m learning. I might be confused on a topic, and that hurts it a lot.”	Danielle: “I don’t like the feeling of people being able to see me. (...) That definitely makes me feel more insecure, and it feeds into the loop of my head of, not necessarily self-hate, but I guess self-doubt. (...) [I doubt] my ability to actually learn and to be good enough to have the spot at the university.”
Motivation	37.9 (11)	Maria: “Being depressed means I already don’t have much motivation in active learning. (...) If you don’t have motivation, it makes it harder to learn things.”	Karla: “I just didn’t have the motivation to do any of [the group activities]. At one point, I almost put my head down on the table just to close my eyes for a little bit because I was just so mentally exhausted and had no real motivation to participate in class that day.”
Memory	24.1 (7)	Julia: “I definitely have a harder time recalling information from class to apply to these group sessions that we do, which leads to getting answers wrong. I have brain fog, forgetfulness.”	Aurora: “When I am at a low point where I feel pretty immobilized, fatigued all the time, pretty much just incapable, I would say I don’t retain much information. Even if I’m doing the work, I can’t recall things particularly.”
Lack of patience/ irritability	20.7 (6)	Jessica: “My depression makes it hard to talk to my peers and to not sound exasperated by them, to make it sound like I want to talk to them. Because I know sometimes I’m really out of it. I almost sound annoyed by people talking to me. I sound very distant.”	Mia: “[Depression affects my social interactions because] I get mad. I get annoyed and I think it’s because I have this fear of being wrong and so I become a little feisty and short tempered because I don’t want to be wrong.”

information better than I can. And I feel that my career is not going to end up well, because I don’t understand the information.”

It can be common for students with depression to describe a “depressive spiral” or an instance when a negative experience in academia leads to a plethora of negative thoughts, often focusing on long-term outcomes (Mohammed *et al.*, 2022). Both Randall and Jennifer alluded to global attributions, or attributing their perceived struggles to factors that affect a wide range of situations (Abramson *et al.*, 1989). In both cases, the stu-

dents emphasize that their specific experiences in active-learning courses have greater implications for their futures in their chosen fields of study.

With regard to clicker questions, instructors oftentimes display a histogram of student responses, and in cases when participants were one of a few students who incorrectly answered a question, it fueled their negative self-talk. Negative self-talk refers to inner dialogue that limits one’s ability to reach one’s full potential (Scott, 2020) and is associated with depression (Kazdin, 1990; Ronan and Kendall, 1994). Isabella and Christina exemplified how realizing others answered a question

correct when they answered it wrong can evoke negative self-talk and exacerbate depression.

Isabella: “[With clicker questions], the [results] are usually exposed right after. And then if I get it right I’m like, ‘Cool.’ And if not, I’m like, ‘Why didn’t I know that?’ This makes me alienate myself. It could be bad. I would say that’s how [active learning] would worsen [my depression].”

Christina: “At the end [of the clicker questions], the professor, she shows the different responses and the percentages of people that chose each response. If you choose a wrong answer and you see that everybody else chose a different answer and it has a higher percentage than the one that you chose, it can cause you [to feel] like you’re dumb and you weren’t able to understand it and a whole bunch of other people were able to understand it. (...) It’s like everybody else is able to pick it up quickly and choose the right answer, but you’re not able to.”

Students who report more negative self-talk obtain poorer academic results compared with students who report less negative self-talk (Sánchez *et al.*, 2016). Academic self-concept, defined as how well individuals feel they can learn (NSW Government Education, 2021), has a reciprocal relationship with both academic engagement and achievement (Craven *et al.*, 2000; Cooper *et al.*, 2018b). A student’s negative self-talk can hinder engagement and achievement, and poor performance can further reduce students’ academic self-concept. As such, avoiding situations that induce negative self-talk may help build student academic self-concept, strengthen student performance, and lessen depressive symptoms.

Feeling Similar to Peers Can Alleviate Depressive Symptoms (48.3%). Indeed, student academic self-concept seemed to be bolstered and depressive symptoms lessened when students compared themselves with others in class who they perceived as similar to themselves. For example, Colette described how her thought process when getting questions incorrect changes when other students are struggling too.

Colette: “When other people are also struggling, it just feels like you have someone else that is in the same boat. Then it’s not so much focused on like, ‘Oh, I don’t understand this. And I feel like an idiot.’ It’s like, ‘Okay, well this is just really hard. And other people are also having a hard time with this.’ And then that puts it into perspective; it’s not just you, it’s everyone who is having a hard time with it.”

Further, Kim explained that when others are also not understanding the material, it helps her realize that she is not the only one who is struggling, which lessens her depression.

Kim: “Being able to connect with someone and be like, ‘Wow, I really don’t understand this concept. I’m not sure.’ And then having them be like, ‘Okay, I don’t really understand it either.’ That connection [makes me] feel like I may not be the only one who’s struggling, which is good for [my depression]. (...) I feel better about the material and less depressed.”

It appears to decrease instances of negative self-talk when students compare themselves with peers they perceive as simi-

lar to themselves. With less negative self-talk, self-esteem is improved, which in turn can alleviate symptoms of depression due to the inverse relationship between self-esteem and depression (Tarlow and Haaga, 1996).

Socializing with Others while Learning. Active learning commonly provides opportunities for students to interact with others in class (Driessen *et al.*, 2020). In alignment with studies investigating the relationship between active learning and anxiety (England *et al.*, 2017; Cooper *et al.*, 2018a; Downing *et al.*, 2020; Baepler, 2021; Hood *et al.*, 2021), we found that student–student interactions have the potential to impact students’ depression in both positive and negative ways.

Increased Opportunities to Be Negatively Evaluated Can Exacerbate Depressive Symptoms (72.4%). Students commonly explained that their depression was exacerbated by fear of negative evaluation (FNE), defined as a student’s sense of dread associated with being unfavorably evaluated while participating in social situations (Watson and Friend, 1969; Weeks *et al.*, 2005). For example, when being cold called, students worried that others may judge them based on their appearance, mannerisms, or way of speaking and whether they answered the question correctly, as described by Amanda and Colette.

Amanda: “If there are times in class where I will answer a question and it’s wrong, I can immediately feel [depression] setting in or that anxiety of, ‘Oh, my gosh. Everyone’s looking at you. Or everyone thinks you’re dumb. Why did you even answer?’ And then that kind of just sits on my shoulders, metaphorically. The rest of the class after that is me just trying to deal with those feelings versus actually learning. It just feels hard to do anything.”

Colette: “Even if I get a question right, I still get really self-conscious about the way that I’m talking or what I said. [I also worry about] the way that I look because people are looking at you when you’re talking. And then I just replay it in my head a million times, what I said and what I looked like when I was doing it. And then I can’t stop thinking about that for a day or two days (...) then that sits in my mind and makes me more depressed.”

Amanda’s and Colette’s descriptions of being negatively evaluated in active-learning courses exacerbating their symptoms of depression mimics the relationship between FNE and anxiety experienced in active learning. FNE is the primary construct underlying student anxiety in active learning, and FNE can exacerbate anxiety even when students are simply anticipating social interactions in class (Downing *et al.*, 2020). Conversely, students with depression only described FNE as exacerbating their depression when they were actually put in a situation where they could be evaluated by others. Students like Amanda and Colette assume that others have already judged them negatively, which would exacerbate common depressive symptoms, such as feelings of worthlessness (Alshawwa *et al.*, 2019).

Struggling to Socialize Can Further Exacerbate Depressive Symptoms (62.1%). In addition to struggling with negative evaluation, students also discussed how navigating social situations

when depressed can further exacerbate depressive symptoms. Participants mentioned struggling to find a group to work with, experiencing challenges when partners were absent, and having trouble socially connecting to other students. Students highlighted how each of these encounters has the potential to increase feelings of isolation and negative self-talk, which can exacerbate their depression, as exemplified by Lucia.

Lucia: “You’re surrounded by a bunch of students and they all seem to already know each other and they pick their own groups, and I kind of feel stuck and I don’t really know anybody. I start to think, ‘Oh, well maybe they don’t think I’m smart enough.’”

The social interactions in active learning can also cause students with depression to feel as though they need to conceal their depression by “putting on a face” or “masking” a depressed mood.

Jessica: “With my depression I can feel really sad or I can feel really empty in a way where I’m not happy. I’m just there. If I’m with other people [in active learning], I have to mask that. I have to act in a way where it looks like I have emotion or it looks like I’m happier than I am. It takes a lot of mental energy for me to put on a mask.”

Depression is an example of a concealable stigmatized identity (Chaudoir and Quinn, 2010), meaning that one’s depression can be concealed and is tied to stereotypes that can result in discrimination (Link and Phelan, 2001; Quinn and Earnshaw, 2010). Students choosing to conceal their depression by masking can further exacerbate their depression, because having and concealing a stigmatized identity can lead to increased psychological distress (Quinn and Chaudoir, 2009; Quinn and Earnshaw, 2010; Quinn *et al.*, 2014). Prior research from our group has found that college science students are often reluctant to reveal their depression in science learning environments, but if learning environments are inclusive and welcoming, then students are more comfortable revealing this important aspect of themselves (Cooper *et al.*, 2020b; Busch *et al.*, 2023).

Microaggressions, Stereotyping, and Feeling Othered in Active Learning Can Exacerbate Depressive Symptoms (20.7%). Participants in the study explained that the increased social interactions in active learning can cause them to feel as though they are different from other students around them in a multitude of ways, such as coming from a lower socioeconomic background, being racially underrepresented in science, or being older. Feeling othered can cause emotional stress, which can contribute to depression (Nadal *et al.*, 2014; Torres and Taknint, 2015). Students, like Aurora, described how being different from other students can lead to instances of discrimination and worsen depression.

Aurora: “It has worsened my depression when there’s lack of collaboration and that lack of collaboration, I believe on a fundamental level is systemic racism. At any time that I felt like I don’t belong, it’s because I’m with a group of white people and they don’t understand my experience. They come in with preconceived notions about what my performance is going to be or I’m talked to like I’m stupid.”

Aurora alluded to experiencing microaggressions in her active-learning courses. Microaggressions are brief, sometimes subtle, everyday exchanges that either consciously or unconsciously disparage others based on their personal characteristics or perceived group membership (Pierce, 1977; Sue, 2010). Microaggressions can impact students by disrupting learning, engagement, and belonging in science (Torres *et al.*, 2010; Wang *et al.*, 2011; Harrison and Tanner, 2018) and the more microaggressions that individuals report, the more likely they are to report symptoms of depression (Nadal *et al.*, 2014; Torres and Taknint, 2015; Auguste *et al.*, 2021). While microaggressions in the classroom have often been documented between instructors and students (Solorzano *et al.*, 2000) or during whole-class discussions (Harwood *et al.*, 2015), the increased student–student interactions in active learning likely provide many more opportunities for these negative interactions to occur.

Positive Experiences Socializing in Active Learning Can Alleviate Depressive Symptoms (79.3%). Although the social interactions in active learning could be challenging for students’ depression, participants like Nora and Jessica highlighted many instances in which connecting with others helped alleviate their depressive symptoms.

Nora: “When you have depression, it’s a very isolating experience, because you feel alone and lonely, but by engaging with others, it kind of makes you feel like you’re grounded again, just even the tiniest bit. [It’s] because you’re able to talk to people about something that’s kind of meaningful too.”

Jessica: “[I experience] a lot of feelings of loneliness. A lot of self-destructive tendencies result in me trying to isolate myself or try to intentionally burn bridges in a way so that I am stuck alone. [Active learning] makes it so that I can’t do those things anymore, because I have to at least interact with one or two people a day, which is nice.”

College can be a particularly lonely time for students (American College Health Association, 2017) and struggling to get to know others, particularly in college science courses, has been shown to exacerbate depressive symptoms among undergraduates (Busch *et al.*, 2022). Therefore, as Jessica suggested, social support can be protective against depression (Charles *et al.*, 2021). Active-learning courses may pose unique remedies to feelings of isolation in college, given the integrated social interactions.

Social Academic Support Can Alleviate Depressive Symptoms (37.9%). When students can socialize and connect with others in active-learning classes, they often leverage the experience to get academic help from their peers (Smith *et al.*, 2009). Participants explained that being able to talk with others, receive help, and benefit from others’ engagement can be particularly helpful during a depressive episode. For example, Christina explained appreciating when other students asked questions, because then she did not have to.

Christina: “[Given my depression], I feel like I’m not at the point yet where I feel comfortable enough to ask questions. So, hearing other people ask the questions, it helps me because somebody else already asked.”

Asking questions of instructors in front of the whole class has been shown to be uncomfortable and anxiety inducing for undergraduates, especially women (Nadile *et al.*, 2021a, b). While this discomfort may be mild for many, it is possible that it is exacerbated in students with depression, given that individuals with depression often have negative views of themselves and may interpret feedback more negatively than intended (Beck, 1967, 1979; Gotlib and Krasnoperova, 1998; Maj *et al.*, 2020). Therefore, having a social network to alleviate some of this stress may be particularly beneficial for students with depression, as Christina described. Additionally, Sofia explained how peers in class can help with specific questions when the student does not understand something.

Sofia: “I feel like having the people around me help me when I don’t understand something (...) or help with alleviating the heaviness on my shoulders and quickly texting people over questions from homework and them explaining helps [decrease feelings associated with depression] too.”

While the benefits of students collaborating in active learning is well documented (Freeman *et al.*, 2014; Smith *et al.*, 2009), increasing evidence suggests that positive social collaborations may be particularly impactful for students who struggle with mental health (Cooper *et al.*, 2018a; Downing *et al.*, 2020).

Frequent Formative Evaluation. A hallmark of active learning is the increased number of formative, low-risk assessments, or opportunities for students to gauge the extent to which they know the material (Ballen *et al.*, 2017; Driessen *et al.*, 2020). Common examples of formative assessments in active-learning college science courses include in-class clicker questions and problem sets. We found that, when students do not perform well on, or fail, these formative assessments, it can exacerbate their depressive symptoms. Conversely, when students perform well, or succeed, on formative assessments, it can alleviate depressive symptoms.

Failing Can Exacerbate Depressive Symptoms (69.0%). When participants experienced failure, broadly defined as the deviation between expected or desired outcomes and actual outcomes (Cannon and Edmondson, 2005; Henry *et al.*, 2019), it could exacerbate their depression, as exemplified by Maria.

Maria: “I know this is the wrong way of thinking, but if I get a question wrong, I attach [my value to it], it’s like, ‘Oh, why did I get that wrong? I’m dumb.’ All those negative feelings. (...) I feel like with being depressed, it’s just kind of not that easy to let it go. I feel like I’m more sensitive to it.”

Maria’s attribution of failure to causes that are internal and unlikely to change (i.e., being dumb) is common among individuals with depression (Klein *et al.*, 1976). Additionally, individuals with depression can be particularly sensitive to setbacks (Cooper *et al.*, 2020a; Gin *et al.*, 2021), as Maria described, and may perceive that, if something fails in a particular context, it is a reflection of them (Miranda and Persons, 1988; Weissman, 2006).

Succeeding Can Alleviate Depression (44.8%). The increased opportunities for failure in active learning mean there are also increased opportunities for success. Students described opportunities to succeed, such as getting clicker questions correct or answering questions correctly when cold called, helped validate students’ intelligence, dampening their depressive symptoms, as described by Lisa.

Lisa: “Especially when I know the answer, and after answering, it’s a good feeling. It’s rewarding almost. It’s like, ‘Oh, I knew.’ It kind of gives you that validation too, like, ‘Oh, doing good.’ It makes me feel smarter too, compared with not knowing the answer, especially when [instructors] call on you.”

Academic validation for students with depression is beneficial because it bolsters their self-efficacy, which is negatively correlated with symptoms of depression (Ehrenberg *et al.*, 1991). In a study exploring students’ experiences with depression in undergraduate research experiences, students discussed how praise and validation are especially beneficial for them, because they have low self-esteem and instances of success can help counteract their already negative self-perceptions (Cooper *et al.*, 2020a).

Engagement in Learning. The definition of active learning put forth by Freeman and colleagues (2014) highlights that active learning engages students in their learning through activities and discussions in class. We found that the increased demand for student engagement in active-learning courses can both help and hinder students’ depression. The directionality of the effect of engagement on depression seemed to be tied to the severity of students’ depressive symptoms; engagement may exacerbate depression when symptoms are severe but alleviate depression when symptoms are milder.

Needing to Engage in Learning Can Exacerbate Depressive Symptoms (55.2%). When depression impacts motivation (Grabinger *et al.*, 2008), participants explained that it can be difficult to simply come to class, let alone engage in their learning by participating in clicker questions and worksheets.

Maria: “Active learning is having to be present. And that may be difficult when you have no motivation, or you just don’t want to actively engage at all times. You kind of have to pay attention and keep engaging for the lecture period. So, I would say, that part is always kind of draining.”

Engaging in active learning may be particularly difficult after students have experienced a depressive episode, defined as a period of depression that persists for at least 2 weeks (Ada’s Medical Knowledge Team, 2022). Research shows that it can be important to take time to recover from a depressive episode and that incomplete recovery may result in increased recurrences of depressive episodes and fewer symptom-free weeks (Judd *et al.*, 2000). Danielle explained how at times she will push herself to go to class and engage, but that can ultimately lead to feelings of hopelessness.

Danielle: “Usually I’ll get anxious about [missing] the assignments or the attendance to class, and then I’ll push myself past

what I should be doing and what I know I should be doing in order to stay healthy. Because I'm so worried about it and it just ultimately leads to me feeling worse about myself. It just compounds the feeling of hopelessness I guess."

Students highlighted that the requirement to engage in an active-learning class was not necessarily limited to in-class situations. They explained how active-learning courses commonly require students to engage with the content in structured ways outside class, which can also take a toll on their depression.

Jessica: "I feel like [my depression] has less to do with the act of learning and more that a lot of active learning in classes inherently makes the class tend to be flipped classroom. It'll make it so we have to watch lectures at home or we have to watch these videos on our own time. And that, for me, is really hard because I'll get home and I'll already be very mentally drained from a day. And having to sit down and watch another lecture is just really hard for me. I need that time to mentally relax and get ready for the next day and to let myself unmask."

Throughout the interviews, students described a common cycle: depression would dampen their motivation (Grabinger *et al.*, 2008), which would make it more difficult to engage in their learning both inside and outside class, which led to decreased academic self-concept and increased feelings of hopelessness and depression (Craven *et al.*, 2000).

Needing to Engage in Learning Can Alleviate Depressive Symptoms (55.2%). For some students, actively engaging in their learning alleviated their symptoms of depression by giving them opportunities to think about course material rather than "being in their head" and focusing on negative thoughts, as they reported sometimes doing in traditional lecture courses.

Julia: "[With depression, I have] brain fog and lose my place and generally feel like my body starts to feel tired (...) and that is just so distracting to me. Active learning kind of pulls me back in. (...) Once I'm in an interactive situation, I feel so much better."

Students also perceived that the opportunity to engage in class enhanced their learning, which alleviated their depression. However, students noted that this was especially true if they were engaging anonymously so that they could avoid judgment from others, as described by Lana.

Lana: "I think [clickers] are a great way [to engage students during class], because it puts everyone on an equal slate. They allow you to remain anonymous, but still [allow] you to really learn, to allow yourself to make mistakes and not fear of being judged or attacking yourself. I definitely do like those poll questions and clicker questions; they definitely alleviate and help my depression."

Studies of the relationship between active learning and anxiety show similar findings (Cooper *et al.*, 2018a; Downing *et al.*, 2020). Students who experience anxiety in active learning reported that active learning can help them better gauge how

they are doing in a course and help them learn more, which alleviates anxiety, but only if they do not fear evaluation from other students.

GENERAL DISCUSSION

In this study, we described specific ways in which depression limits students' experiences in active learning and identified four overarching aspects of active learning that can positively and negatively affect student depression: opportunities to compare self with others, socializing with others while learning, frequent formative evaluation, and engagement in learning (Figure 1). Here, we address why a single aspect of active learning can have differing effects on depressive symptoms and what instructors can consider in efforts to create more inclusive active-learning courses for students with depression.

Opportunities to Compare Self with Others

Students have opportunities to compare themselves with others in both a positive and negative manner in active-learning science courses. Many students discussed how comparing themselves with others who they perceive as better students can lead to negative self-talk, but students also discussed how they feel less alone when other students are also struggling. Cognitive theories of depression suggest that individuals with depression can display dysfunctional cognitive schemas that can lead them to have negative thoughts about themselves and the world (Beck, 1979; Gotlib and Krasnoperova, 1998; Maj *et al.*, 2020). Therefore, what may seem like an insignificant comparison (e.g., realizing you got a clicker question wrong when 93% of the class got it right) can have a notable negative impact on the self-concept of a student with depression. Conversely, understanding that other students are also struggling may be especially beneficial for a student with depression, because it helps combat negative thoughts resulting from dysfunctional cognitive schemas. Emphasizing instances when all students struggled with a question, as opposed to when most students understand a question, may be beneficial to these students (Cooper *et al.*, 2018a).

Socializing with Others while Learning

While the inherently social aspect of active-learning courses was the most common aspect of active-learning practices that alleviated symptoms of depression in participants, it was also mentioned as an aspect of active-learning practices that exacerbated depressive symptoms. While this may appear contradictory, the primary difference between whether increased socialization in active learning alleviated or exacerbated depressive symptoms seemed to be dependent on whether the social interaction was supportive. Social support is protective against depression (Charles *et al.*, 2021), and many participants in our study discussed how support decreases feelings of isolation, lessening depression. Alternatively, social interactions that caused students to feel isolated, othered, stereotyped, or microaggressed exacerbated students' depression. Instructors can maximize the likelihood of the social aspects of active learning alleviating depressive symptoms by allowing students to develop relationships with others in class by having students choose where to sit in class and minimizing the extent to which students change groups throughout the term (Cooper and Brownell, 2016; Cooper *et al.*, 2018a; Downing *et al.*, 2020). Further, instructors can increase awareness about microaggressions in the classroom

Overarching aspect of active learning	Aspect of active learning that exacerbates depressive symptoms	Aspect of active learning that alleviates depressive symptoms	Suggestions for creating an inclusive classroom for students with depression
Opportunities to compare self with others	Comparison with others that results in a student feeling inferior	Comparison with others who students perceive as similar to themselves	Emphasize instances when all students struggled with a question to help students realize that others struggle too.
Socializing with others while learning	Increased opportunities to be negatively evaluated	Positive experiences socializing	Identify ways to promote positive relationships among students, such as allowing students to choose where to sit and minimizing the number of times students switch groups per term.
	Struggling to socialize when experiencing depression		
	Microaggressions, stereotyping, and feeling othered	Social academic support	
Frequent formative evaluation	Frequent opportunities to fail	Frequent opportunities to succeed	Pair difficult assessments with assessments that students are likely to complete successfully. Encourage a growth mindset.
Engagement in learning	Large bandwidth needed which can feel draining	Distraction from depressive symptoms and negative thoughts	Consider allowing students to opt out of active-learning activities on days when their depression is severe.

FIGURE 1. Summary of aspects of active learning that exacerbate and alleviate depressive symptoms and recommendations for instructors.

by prompting discussions about microaggressions (Boysen, 2012; Darwin, 2018) to decrease students' chances of being microaggressed and stereotyped.

Frequent Formative Evaluation

The reciprocal relationship between academic self-concept and academic achievement (Craven *et al.*, 2000) helps explain the relationship between opportunities for success and failure and the impact of each on depression. Opportunities to succeed allow for academic achievement, which positively impacts academic self-concept. Inversely, opportunities to fail decrease academic achievement, which negatively impacts students' academic self-concept. Improved academic self-concept decreases likelihood of the negative self-talk associated with depressive symptoms (Kazdin, 1990; Ronan and Kendall, 1994). Behavioral theories of depression suggest that infrequent response-contingent positive reinforcement (e.g., sporadic and challenging clicker questions) can increase cognitive symptoms of depression such as low self-esteem (Lewinsohn, 1974; Kanter *et al.*, 2004); therefore, opportunities for success are important in active-learning courses. These cognitive and somatic symptoms of depression may be decreased through increased opportunities for success and positive reinforcement in active-learning science courses (Lewinsohn, 1974; Martell *et al.*, 2001; Manos *et al.*, 2010). However, frequent opportunities for failure can exacerbate dysfunctional cognitive schemas held by individuals with depression; individuals with depression may take small failures and allow them to fuel larger negative thoughts about themselves (Miranda and Persons, 1988). Instructors can ensure that more difficult formative assessments are paired with frequent opportunities for success so that students are likely to

experience success in addition to failure. Instructors can also encourage a growth mindset rather than a fixed mindset; individuals with a fixed mindset more frequently view academic challenges as something to be avoided (Henry *et al.*, 2019).

Engagement in Learning

By definition, active learning is inherently engaging, which is what distinguishes it from traditional lecture (Driessen *et al.*, 2020). Whether or not the inherently engaging aspect of active-learning practices exacerbates or alleviates students' depressive symptoms is situational and likely depends in part upon the state or severity of a student's depression. Students discussed many ways in which the inherently engaging aspect of active-learning courses both exacerbates and alleviates their depression. When discussing the negative impact of the inherently engaging aspect of active-learning courses, students discussed how active learning requires more energy than a traditional lecture course and that can take away from energy they may need to prioritize their mental health. Engaging in active-learning practices might be especially hard for students with depression because of the impact depression has on their cognitive domains, including motivation (Grabinger *et al.*, 2008; Mohammed *et al.*, 2022). Conversely, students explained that the positive impact of the inherently engaging aspect of active-learning courses was that it kept their mind off depressive thoughts. Some ways to maximize the benefits of the inherently engaging aspect of active-learning courses would be to not require students to engage on days their depression is exacerbated. However, more research is required to understand the nuanced relationship between engagement and depressive symptoms.

Limitations and Future Directions

The 29 students enrolled in the study were primarily women, Asian, and in their third year of college or earlier. Therefore, these findings should not be generalized beyond particular student populations. While the percentages of students from particular demographic groups in this study were roughly representative of the percentage of students from those demographic groups enrolled in the institutions from which they were recruited, we recognize that they are not representative of students enrolled in college across the United States (U.S. Census Bureau, 2018). Additionally, all students in the study identified as having anxiety, and we did not attempt to examine which underlying aspects of active learning affected students' depression but not their anxiety. During the interviews, we asked students about their experiences in active-learning college science courses but did not ask how long ago they were enrolled in the courses that they chose to speak about; thus, some students may be recalling courses that they previously participated in, and their responses may be impacted by recall bias, defined as the embroidery of personal history by participants (Raphael, 1987). Additionally, we asked the interview questions in the same order for each participant. While we intentionally designed the interviews in this way based on feedback during think-aloud interviews before data collection (Trenor *et al.*, 2011), we recognize that by always asking students to describe the ways in which an active-learning practice exacerbates their depression before asking how it alleviates their depression may have affected their responses.

The sample size of the study was 29 students, which may be considered small. However, saturation was reached in the first 24 interviews, so we felt that further interviews were not necessary (Guest *et al.*, 2006). Furthermore, a sample of this size has been common in 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). In future larger quantitative studies, it would be useful to examine the extent to which student demographics predict the experiences of students with depression in active-learning courses. This would help instructors to design more inclusive active-learning courses. While we understand that it is contradictory that some aspects of active-learning practices both exacerbated and alleviated students' depressive symptoms, we know that this is because depression manifests differently among individuals (NHS, 2021), and the ways in which depression affects students' experiences in active learning can be situational. To address this in the future, it would be beneficial to ask if a certain underlying aspect of active-learning practices exacerbates or alleviates their depressive symptoms to a greater extent and what recommendations students may have for preventing the negative outcomes of that underlying aspect.

CONCLUSION

Active learning is an effective practice to enhance student learning and decrease failure rates (Freeman *et al.*, 2014; Theobald *et al.*, 2020); to further maximize the positive impact of active learning, this study sought to examine the relationship between engaging in active learning and undergraduate depression. In this exploratory interview study, we found that depression negatively impacted students' experiences in active-learning college science courses by affecting their social interactions, mem-

ory, focus, motivation, energy, patience, and self-doubts about intelligence. Additionally, we identified four aspects of active learning that could both exacerbate and alleviate students' depressive symptoms: opportunities for comparison with others, social interactions in active learning, frequent formative evaluation, and opportunities for engagement. We hope that this study helps those reforming undergraduate science curricula better understand students' experiences with depression in active-learning science courses to help ensure active-learning practices are implemented in a more inclusive way for students struggling with mental health.

Important Note

If you or someone you know is struggling with depression, there are resources available. Many colleges and universities provide walk-in and online counseling services in addition to crisis hotlines, which can be found by visiting the university health center website. National mental health helplines are also available; the Suicide and Crisis Lifeline (988) is available for free 24/7 and the National Alliance on Mental Illness offers support to people struggling with mental health Monday through Friday from 10:00am to 8:00pm Eastern (1-800-950-6264 (NAMI) or www.nami.org/help). For additional information about depression or resources near you, visit the Anxiety and Depression Association of America website (adaa.org) or the Depression and Bipolar Support Alliance website (dbsalliance.org).

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