What I Wish My Instructor Knew: How Active Learning Influences the Classroom Experiences and Self-Advocacy of STEM Majors with ADHD and Specific Learning Disabilities

Mariel A. Pfeifer, Julio J. Cordero, and Julie Dangremond Stanton*
Department of Cellular Biology, University of Georgia, Athens, GA 30602

ABSTRACT
Our understanding of how active learning affects different groups of students is still developing. One group often overlooked in higher education research is students with disabilities. Two of the most commonly occurring disabilities on college campuses are attention-deficit/hyperactivity disorder (ADHD) and specific learning disorders (SLD). We investigated how the incorporation of active-learning practices influences the learning and self-advocacy experiences of students with ADHD and/or SLD (ADHD/SLD) in undergraduate science, technology, engineering, and mathematics (STEM) courses. Semistructured interviews were conducted with 25 STEM majors with ADHD/SLD registered with a campus disability resource center at a single university, and data were analyzed using qualitative methods. Participants described how they perceived active learning in their STEM courses to support or hinder their learning and how active learning affected their self-advocacy. Many of the active-learning barriers could be attributed to issues related to fidelity of implementation of a particular active-learning strategy and limited awareness of universal design for learning. Active learning was also reported to influence self-advocacy for some participants, and examples of self-advocacy in active-learning STEM courses were identified. Defining the supports and barriers perceived by students with ADHD/SLD is a crucial first step in developing more-inclusive active-learning STEM courses. Suggestions for research and teaching are provided.

INTRODUCTION
Students with disabilities are one of the largest underrepresented groups of students within college science, technology, engineering, and mathematics (STEM) courses and nearly 20% of undergraduates report a disability (National Science Foundation [NSF], 2021). College STEM instructors typically receive limited, if any, pedagogical training to support students with disabilities in their courses (Love *et al.*, 2015). Moreover, few studies examine how specific teaching practices influence the experiences of students with some of the most common disabilities within undergraduate STEM courses. Limited pedagogical training and finite empirical knowledge of student experiences are likely contributing to the attrition of students with disabilities from STEM majors. We conducted an exploratory study using participant interviews to advance our understanding of how active learning affects students with disabilities. In this study, we center the voices of STEM majors with attention-deficit/hyperactivity disorder (ADHD) and specific learning disorders (SLD) to characterize how they perceive various active-learning practices in their undergraduate STEM courses as influencing their learning and their self-advocacy. Our participants were registered with a campus disability resource center. Understanding the perspectives of students with ADHD/SLD is needed, because they are experts about their own experiences, and in our view, many

Rebecca Price, *Monitoring Editor*
Submitted Dec 7, 2021; Revised Oct 6, 2022; Accepted Nov 1, 2022
CBE Life Sci Educ March 1, 2023 22:ar2
DOI:10.1187/cbe.21-12-0329
*Address correspondence to: Julie Dangremond Stanton (stantonj@uga.edu).

STEM courses were designed with limited, if any, consideration for their unique needs or preferences. In the following sections, we build the scholarly context for our study by introducing our study population and summarizing what is currently known about how active learning influences the experiences of students with disabilities in undergraduate STEM courses. We then present our guiding theoretical framework and research questions.

Students with Disabilities in STEM

Students with disabilities are interested in pursuing STEM majors. In fact, students with disabilities show similar rates of STEM major selection as students without disabilities (Lee, 2022). Although interested in STEM, many students with disabilities will leave their initially intended STEM majors before completing a STEM degree (NSF, 2021). Multiple factors contributing to the attrition of students with disabilities from STEM have been identified. Briefly, these factors include a lack of support during the transition to college, problems accessing effective academic accommodations in STEM courses, issues with the physical and digital accessibility of STEM courses and labs, a dearth of STEM instructor knowledge regarding disability and accommodation use, and student perceptions of STEM as an unwelcoming climate for students with disabilities (e.g., Hedrick *et al.*, 2010; Dunn *et al.*, 2012; Moon *et al.*, 2012; Hong, 2015; Love *et al.*, 2015; Thurston *et al.*, 2017; Miller and Downey 2020; Friedensen *et al.*, 2021; Nieminen and Pesonen, 2020, 2022; Batty and Reilly, 2022). Inherent ableism, or the "stereotyping, prejudice, discrimination, and social oppression toward people with disabilities," exists within many STEM contexts, which contributes to a sense of non-belonging for students with disabilities (Bogart and Dunn, 2019, p. 650; Nieminen and Pesonen, 2020, 2022). Many previous studies of STEM students with disabilities aggregate students with diverse disability types into one category. Yet individual experiences of disability differ. For instance, a recent study of disability service providers found that college students with ADHD were perceived to be less deserving of accommodations than students with visual impairments (Druckman *et al.*, 2021). Few studies untangle how the experiences of students with certain types of disabilities are affected by particular STEM learning environments or specific teaching practices. This aggregation of students and teaching practices limits our understanding of the individual nature of disability and how certain teaching practices implemented by STEM instructors affect students. Advancing our knowledge of the experiences of students with disabilities requires a finer-grained approach to more fully understand their experiences in undergraduate STEM courses.

Our study focuses on the experiences of students with two types of related disabilities, ADHD and/or SLD (ADHD/SLD). ADHD and SLD are examples of neurodevelopmental disorders and are among the most common disabilities reported by college students (Raue and Lewis, 2011; American Psychological Association, 2013). SLD includes specific learning disorders in reading (formerly called dyslexia), writing (dysgraphia), or mathematics (dyscalculia; American Psychological Association, 2013). Previous research shows that students with ADHD and SLD can experience similar challenges with motivation, anxiety, and monitoring for understanding (Reaser *et al.*, 2007). Students with ADHD and SLD are frequently studied concurrently, because they share similar learning experiences, ADHD and SLD often co-occur, and both ADHD and SLD are examples of nonapparent disabilities (DuPaul *et al.*, 2013). Nonapparent disabilities are "impairments with physical and psychological characteristics that are not readily recognized by an onlooker" (Thompson-Ebanks and Jarman, 2018, p. 287). Due to the nonapparent nature of ADHD and SLD, STEM students with ADHD/SLD often need to self-disclose their disability status to others to explain that they qualify for accommodations or to explain their use of accommodations to those who assume they do not have a disability. This need for self-disclosure is thought to influence the receipt of accommodations. College students with learning disabilities report a lower rate of accommodation receipt compared with students with other types of disabilities (Newman *et al.*, 2011).

The Strengths of STEM Students with ADHD/SLD

Few studies examine the strengths of individuals with ADHD and SLD and how these strengths are an asset for STEM-related pursuits. This may be due to how disability diagnoses are perceived in our current educational systems and how Western culture often views disability as being at odds with success in STEM (e.g., Shifrer and Mackin Freeman, 2021). Here, we highlight the strengths students with ADHD and SLD can possess. Hyperfocus, or a "state of heightened, intense focus of any duration, which most likely occurs during activities related to one's school, hobbies, or screen time," is a potential example strength that STEM students with ADHD possess (Hupfeld *et al.*, 2019). STEM students with ADHD described how hyperfocusing allowed them to become highly detail oriented when completing course exams (Pfeifer *et al.*, 2020). Participants with ADHD in another study named their high energy levels as an asset for their work (Lasky *et al.*, 2016). Participants perceived themselves as performing best in jobs that entail "stress or mental challenge, novel or varied tasks, physical labor, hands-on work, or topics of intrinsic interest" (Lasky *et al.*, 2016, p. 165). These descriptors have the potential to align with the contexts STEM undergraduates encounter, making some undergraduate STEM contexts an environment where students with ADHD will excel. College students with SLD in reading demonstrated enhanced spatial learning compared with students without SLD in reading (Schneps *et al.*, 2012). This finding suggests that students with SLD in reading may be well suited for STEM pursuits requiring extensive visual processing skills, such as radiology, astronomy, and microscopy (Schneps *et al.*, 2012). More research is needed to fully understand the unique strengths of STEM students with ADHD/SLD and how undergraduate STEM courses can be designed to be more compatible with these strengths.

Active Learning in STEM

"Active learning" is a term representing many different forms of teaching practices in undergraduate STEM courses (Lombardi and Shipley, 2021). It is generally recognized as a contrast to lecture, in which the instructor talks while students passively listen. Many biology education research studies define active learning by describing the types of active-learning strategies or practices present within a certain course (Driessen *et al.*, 2020). For instance, active-learning strategies can include students engaging in clicker questions, group work, worksheets or problem sets, and class discussions. "Flipped classrooms" are also discussed in the context of active learning in undergraduate STEM courses (e.g., Lombardi and Shipley, 2021). Flipped courses involve students acquiring knowledge from either prerecorded lectures or instructor-selected readings or videos outside class (Bergmann and Sams, 2012; O'Flaherty and Phillips, 2015). In flipped courses, in-class time can be used to address student questions from their outside classwork or by engaging students in activities and other cognitive work.

"Course structure" is another aspect of active-learning STEM courses (e.g., Eddy and Hogan, 2014). Course structure can be broadly thought of as the processes and approaches that help students maximize their learning and engagement (Tanner, 2013; Waugh and Andrews, 2020). Some of the benefits of active-learning instruction may result from increased course structure, which can provide students with more practice and feedback and create more-inclusive learning environments. For example, Eddy and Hogan (2014) documented that transforming one course from low to moderate structure—specifically, adding guided-reading questions, preparatory homework, and in-class activities—increased the performance of the entire class while also closing achievement gaps for Black students and first-generation students.

However, not all implementation of active learning leads to increased student learning outcomes. In a population of randomly selected introductory biology instructors, active learning was not associated with enhanced student learning of natural selection (Andrews *et al.*, 2011). The factors contributing to the nuanced outcomes of active learning are not fully understood. Contributing factors may include issues with implementation of active-learning practices by instructors (e.g., Stains and Vickrey, 2017), as well as the potential for active learning to negatively affect certain groups of students within STEM courses (e.g., England *et al.*, 2017; Cooper *et al.*, 2018).

Active learning is often assumed to be an inclusive teaching pedagogy with the potential to enhance student learning relative to passive lecture, especially for higher-order cognitive tasks (e.g., Beichner *et al.*, 2007; Haak *et al.*, 2011; Eddy and Hogan, 2014; Freeman *et al.*, 2014; Dewsbury and Brame, 2019; Theobald *et al.*, 2020). Indeed, a long line of research in college and K–12 settings indicates that active-learning practices are generally effective for students and that active-learning practices are generally feasible and worthwhile for many groups of students (e.g., Freeman *et al.*, 2014; Theobald *et al.*, 2020; Satparam and Apps, 2022). Yet relatively few studies have examined how different student groups are affected by different types of active learning in undergraduate STEM courses. For instance, certain active-learning practices are known to affect students with self-reported anxiety in some classrooms (England *et al.*, 2017; Cooper *et al.*, 2018; Brigati *et al.*, 2020; Downing *et al.*, 2020; Hood *et al.*, 2021). While anxiety can serve as an impetus for students to study, high levels of anxiety can impede academic performance (Seipp, 1991; Downing *et al.*, 2020). Active learning may also affect the experiences of students with LGBTQIA identities in the classroom. Specifically, active learning was found to "increase the relevance of LGBTQIA identities" with the potential to influence feelings of belonging within the classroom environment (Cooper and Brownell, 2016, p. 8). Our understanding of how active learning influences different groups of students is still evolving.

Active Learning and STEM Students with Disabilities

Some literature suggests that active learning is challenging for students with disabilities (Gonzalez, 2017; Gin *et al.*, 2020; James *et al.*, 2020; Nieminen and Pesonen, 2020, 2022). In an interview study with 37 campus disability resource center (DRC) directors, several aspects of active learning were identified that could negatively influence the experiences of STEM undergraduates with disabilities (Gin *et al.*, 2020). For instance, DRC directors stated that students with learning disabilities[1] could experience difficulty with group work and clicker questions (Gin *et al.*, 2020). We note that DRC directors are likely most familiar with the challenges of active learning, and not necessarily the benefits of active learning for students, because they may or may not be meeting with students directly in their day-to-day work. In our own experiences, DRC directors are typically called upon when an accommodation problem needs to be solved, not necessarily when accommodations are working well for students. This study highlights issues about active-learning implementation that STEM instructors should know. To complement this work, we need to consider the voices of current STEM students themselves.

A few studies have begun to address the need for student voice. One study found students with learning disabilities in undergraduate STEM courses preferred hands-on learning, which can be assumed to share some features with active learning, and participants reported lecture as their least preferred learning method (Cox *et al.*, 2019). In a separate study of three participants with ADHD in an active-learning physics course, participants reported both benefits and barriers to their learning because of active learning. This study was conducted in a Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP[2])-inspired introductory physics course that used active-learning practices (James *et al.*, 2020). One participant reported that the SCALE-UP course supported their learning because there was "space for being distracted" and that the nature of the SCALE-UP course allowed them "autonomy in how they learned the material" that was conducive to them as a student with ADHD (James *et al.*, 2020, p. 16). The remaining two participants reported barriers to their learning; the physical arrangement of the classroom was distracting to them, and they were unsure of how to prepare outside class for the in-class active-learning practices (James *et al.*, 2020). Another study of three undergraduate mathematics students with disabilities in a flipped course in Finland showed that, for some students, the flipped nature of the course supported their learning by providing a structure that allowed them to learn material independently (Nieminen and Pesonen, 2020). However, at least one participant ended up withdrawing from the course. The participant attributed withdrawing from the course to difficulties using technology, perceived anxiety and stress of completing frequent assignments, and perceived necessity of social interaction to ask for help (Nieminen and Pesonen, 2020). Together, these studies suggest that active learning is

[1]Learning disabilities in this study included dyslexia, ADHD, and autism.

[2]SCALE-UP courses are implemented in classrooms that are uniquely designed to permit efficient group work, with students typically sitting around circular tables containing computers or laptops with multiple projector screens and dry-erase boards arranged at the periphery of the room to facilitate sharing of information with the entire class (Beichner *et al.*, 2007).

likely imparting a more nuanced effect upon students with ADHD and learning disabilities than previously recognized. Fuller understanding of this effect can help in optimizing supports and minimizing barriers, which would likely lead to the generation of more-inclusive active-learning STEM courses. Further research is required to more fully understand how implementation of active learning affects students with ADHD and SLD in different institutional contexts and across STEM disciplines.

Our Current Study

The purpose of our study is to characterize the learning and self-advocacy experiences of students with ADHD/SLD in undergraduate STEM courses that incorporate aspects of active learning, that is, active-learning practices. We conducted this study at a single university. We predicted that, because active-learning practices were likely designed without consideration for the experiences of students with ADHD/SLD, certain active-learning practices could negatively affect our participants. Students with ADHD and SLD may need to use self-advocacy in this type of situation. Self-advocacy is defined as the "ability to assertively state wants, needs and rights, determine and pursue needed supports" and to obtain and evaluate the needed support with the ultimate goal of conducting affairs independently (Izzo and Lamb, 2002, p. 6; Martin and Marshall, 1995; Pfeifer *et al.*, 2021). Students with disabilities use self-advocacy to procure the accommodations and supports they need to access learning in a classroom. A student with self-advocacy is aware of how their disability affects their learning and understands their rights as an individual receiving services under federal law (Test *et al.*, 2005). STEM students with self-advocacy also know the process to obtain accommodations and what accommodations they can request from their college or university and are cognizant that STEM learning contexts vary, which may influence their accommodation needs (Pfeifer *et al.*, 2020). STEM students with self-advocacy engage in different behaviors, such as communication, leadership, and filling gaps to ensure their success (Test *et al.*, 2005; Pfeifer *et al.*, 2020). Moreover, self-advocacy for STEM students is influenced by beliefs such as view of disability and agency (Pfeifer *et al.*, 2020). We used the emerging theory from our conceptual model of self-advocacy (see Table 1 for components) to define self-advocacy in this work.[3]

For undergraduate STEM students with ADHD/SLD, self-advocacy is influenced by many internal and external factors (Pfeifer *et al.*, 2021). Internal factors, or aspects within an individual, include the total self-advocacy knowledge an individual holds, their self-advocacy beliefs, and their additional identities, such as racial and gender identities. External factors are aspects beyond the level of an individual student. Example external factors include other individuals, such as peers, families, and DRC coordinators, as well as the classroom environment. Classroom environment, which involves the language and actions taken by STEM instructors, is a major influence on the self-advocacy of STEM undergraduates with ADHD/SLD. In our previous work, we identified that students perceived STEM instructors to support and, in some cases, hinder self-advocacy (Pfeifer *et al.*, 2021). For instance, STEM instructors could support self-advocacy for students with ADHD/SLD by verbally affirming their use of accommodations in a course. Conversely, STEM instructors could hinder self-advocacy when they lacked knowledge about the instructor's role in the accommodation process or through actions like adopting anti-technology policies in their courses. Given the effect of classroom environment upon self-advocacy, we reasoned that self-advocacy experiences of students with ADHD/SLD could be influenced by other aspects of the classroom environment, such as active learning. Understanding how active learning affects self-advocacy can aid development of more-inclusive classrooms. Supporting student self-advocacy may help students with ADHD/SLD feel more comfortable disclosing their disability, which could enhance the number of STEM students who register with the DRC and use accommodations in STEM.

This study is a component of a larger study regarding the self-advocacy experiences of STEM undergraduates with ADHD/SLD (Pfeifer *et al.*, 2020, 2021). Here, we address two specific research questions by conducting semistructured interviews with 25 STEM majors with ADHD/SLD.

Research Question 1. What aspects of active learning influence students' perceptions of learning? We define perceptions of learning as how a participant reports their own knowledge acquisition to be affected by a teaching practice or feature of the class.

Research Question 2. How does active learning influence the self-advocacy of our participants?

METHODS

We recruited 25 STEM majors with ADHD/SLD during the Fall 2018 and Spring 2019 semesters at a large research-intensive university in the southeastern United States in partnership with a DRC in an accessible and confidential manner, as we have previously described (Pfeifer *et al.*, 2020, 2021). In Fall 2018, 152 STEM majors were registered with the DRC and eligible to receive accommodations for either ADHD or SLD as a primary or secondary condition. Of these 152 potential participants, 56% identified as women, 43% identified as men, and 1% identified as unspecified. The first 25 students who agreed to participate in our study from the pool of 152 potential participants were selected to complete a semistructured interview. A summary of participant characteristics is presented in Table 2. All participants provided informed consent and were compensated $20 for completing the study. The study was deemed exempt for Institutional Review Board review (STUDY00004663). We provide an extended description of our methods as Supplemental File 1, which includes our positionality statement, a summary of how participant responses were elicited during the interview, and a section discussing the trustworthiness of our study.

Data Collection: Screening Survey

Participants first completed a brief online screening survey (Supplemental File 2). The purposes of the survey were to: 1) confirm participant eligibility for the study, 2) collect information about participant familiarity with active-learning

[3]In an ideal world, students with disabilities would not need to engage in self-advocacy to receive the accommodations or supports they need within an active-learning STEM course. Self-advocacy can be perceived as a burden to students. Yet it is viewed as critical for student success in our current educational system (Janiga and Costenbader, 2002; Daly-Cano *et al.*, 2015).

TABLE 1. Definitions of self-advocacy components from our model of self-advocacy for students with ADHD/SLD in undergraduate STEM courses (communication is bolded because it is required for self-advocacy)

Self-advocacy component	Definition
Knowledge of self	Awareness of individual strengths and weaknesses as a learner with a disability[a]
Knowledge of rights	"Knowing one's rights as a citizen, as an individual with a disability, and as a student receiving services under federal law" (Test *et al.*, 2005, p. 50)
Knowledge of STEM learning contexts	Awareness that accommodation needs are influenced by the learning environment experienced by students with ADHD/SLD in undergraduate STEM courses[b]
Knowledge of accommodations	Awareness of: 1. accommodations that are available to a student with ADHD and/or SLD, and 2. how the accommodation process in college works, including knowledge of the student role, the DRC coordinator role, and the instructor role in the process[b]
Communication	Communication for the purpose of self-advocacy involves "negotiation, assertiveness, and problem-solving in a variety of situations" (Test *et al.*, 2005, p. 50)
Leadership	Taking action for others with diagnosed disabilities to overcome stigma and advocating for peers without formally diagnosed disabilities to be tested to receive academic accommodations[b]
Filling gaps	Participants taking action to mitigate a perceived limitation in either their formal accommodations from the DRC or a perceived limitation in the instructional practices used in a STEM course[b]
View of disability	Individual student view of their own disability, and their perceptions of how STEM instructors, and peers view disability and accommodation use in the context of undergraduate STEM courses[b]
Agency	An individual belief that an individual student with a disability is responsible for their own accommodations and success in college[b]

[a]Definition from Test *et al.* (2005).
[b]Definition from Pfeifer *et al.* (2020).

practices in STEM courses, and 3) customize questions included in the interview protocol. The screening survey asked participants to indicate their major, year in school, and disability type and to confirm they were 18 years of age or older. In addition, the survey asked participants to indicate all the STEM courses they were enrolled in or had completed at

TABLE 2. Summary of participant characteristics[a]

Participant	STEM major	Disability[b]	Gender	Year[c]
Allissa	Engineering	ADHD	Woman	Fourth
Brett	Engineering	ADHD	Man	Fifth and up
Bryce	Life science	ADHD	Man	Second
Carson	Mathematics related	Both	Man	Fifth and up
Dylan	Life science	ADHD	Man	Second
Elliott	Life science	ADHD	Man	Fourth
Erik	Mathematics related	Both	Man	First
Felix	Engineering	Both	Man	Fourth
Jack	Physical science or technology	SLD	Man	First
Jessa	Physical science or technology	ADHD	Woman	Third
Josiah	Life science	SLD	Man	First
Kacey	Life science	ADHD	Woman	Second
Lena	Engineering	ADHD	Woman	Fifth and up
Lucas	Life science	ADHD	Man	Third
Mark	Life science	ADHD	Man	Fifth and up
Olen	Life science	ADHD	Man	Third
Penny	Engineering	Both	Woman	Fifth and up
Sadie	Engineering	ADHD	Woman	Fifth and up
Stella	Physical science or technology	Both	Woman	Third
Stewart	Life science	ADHD	Man	Third
Therese	Life science	ADHD	Woman	Third
Thomas	Engineering	SLD	Man	Fifth and up
Vivian	Life science	SLD	Woman	Fourth
Wren	Life science	ADHD	Woman	Third
Zara	Life science	SLD	Woman	Third

[a]Race is not reported at the individual level to protect confidentiality. Out of 25 participants, two participants are Black and 23 are white.
[b]"Both" indicates both ADHD and SLD.
[c]Year indicates year in college. "Fifth and up" indicates participants in their fifth year or greater of college.

the time data were collected. A description of active learning was provided for reference in the survey (see Supplemental File 2). Examples of student activities that may indicate active learning were included in the survey and were derived from the "student doing" codes of the Classroom Observation Protocol for Undergraduate STEM (COPUS; Smith *et al.*, 2013). Participants were then asked if their STEM instructors used active-learning practices and to select which practices they remembered their instructors using in their most recent STEM courses. Besides the provided example active-learning practices, participants could also select "other" or "don't remember." If participants selected "other," they were prompted to describe that practice. After completing the screening survey, participants completed a semistructured interview, typically within 24 to 48 hours.

Data Collection: Interviews

We conducted a semistructured in-person interview with each participant. The average length of the interviews was 80 minutes. During the interviews, participants discussed their experiences in primarily lecture STEM courses and in STEM courses that incorporated active-learning practices. Interview questions related to this study are available in Supplemental File 3. The course information collected in the screening survey was used as the basis for question 1 in the interview protocol. Following the interview, participants completed a short demographic survey. Interviews were transcribed by a third-party service, and each resulting transcript was checked for accuracy before analysis.

Data Analysis

We analyzed data using a primarily inductive, or data-driven, approach as opposed to a deductive, or theory-driven, approach. This type of approach was appropriate for our study, because there was no existing comprehensive framework of active learning and the experiences of STEM students with ADHD/SLD that we could use for deductive coding. For instance, while we provided participants with a list of possible active-learning practices derived from the "student-doing" codes of the COPUS, this was not an exhaustive or descriptive list of active-learning practices (Smith *et al.*, 2013). Thus, participants identified the teaching practices they considered to be examples of active learning and the aspects of active-learning courses that affected them, and they discussed in the interview how these practices influenced their learning and self-advocacy. Using a heavily inductive approach allowed us to center our participants' voices while answering our research questions.

During data analysis, we worked as a coding team. We found that approaching our analysis in steps enabled us to most efficiently analyze our data as a team. We frequently checked in with our fellow coders one to two times per week as we progressed through the data. We first identified relevant segments of the interview that addressed our research questions. From there, we initial coded the data to understand the range of participant experiences in terms of both active learning and self-advocacy and to discuss how the data could address our research questions (Saldaña, 2016). We then developed a coding matrix to use for analysis (Supplemental File 4). This matrix was used by each researcher individually to analyze the interviews in our first-cycle coding step. Here, we used in vivo coding and descriptive coding. In vivo coding uses the actual language of the participants as the code name, and descriptive coding uses words and short phrases to summarize the topic a participant discusses (Saldaña, 2016). Some of our descriptive codes were a priori codes from the "student doing" codes of the COPUS (Smith *et al.*, 2013). Our goal in first-cycle coding was to preserve the language participants used to discuss their own experiences whenever possible. After coding a set of four to five interviews, the researchers met to discuss how data were coded and to resolve coding differences. In this meeting, a final combined coding matrix was generated that reflected our mutual understanding of the data from a single participant. These data were our finalized first-order codes.

The final coding matrices, which contained our first-order codes, were then used as the basis to begin proposing themes, or abstractions of the coded data. One researcher (M.A.P.) took the lead in compiling the themes and subthemes into tables and shared the resulting tables with the other researchers. We met to discuss the themes and subthemes and to resolve any disagreements. Our themes and subthemes were also presented to qualitative researchers who were unfamiliar with our data corpus for feedback and discussion about the resulting themes and subthemes. This feedback helped us clarify our themes and subthemes. We also generated many different visual representations of our data to help refine themes and subthemes. Analytic memos were kept throughout the entire data analysis process to help track and monitor our reactions, decisions, and interpretations.

Limitations

Active learning in our study was broadly defined to allow the most salient features of participant-selected active-learning practices to emerge from the interviews. We acknowledge that, in our study, the "tools, e.g., clickers" and the "actual methodology of active learning" are presented simultaneously (Eddy *et al.*, 2015, p. 2). Our data reflect the perception of our participants and do not include instructor interviews or classroom observations. We caution that additional research is needed to make conclusive statements about the efficacy of any one active-learning practice for students. Data were collected at one institution. All of our participants were registered with the DRC at the time of the study. It is unclear whether our research findings apply to students at other institutions or students who qualify for accommodations but are not yet receiving formal accommodations.

We clarify the purposes and limitations of our analysis to aid readers in determining the transferability of our results to other contexts. We did not design our analysis process to determine, broadly, how all types of instructional practices (active learning or lecture based) affect our participants. Here, we focus on participant perceptions of active-learning practices in their undergraduate STEM courses. Additionally, a majority of our participants were white, men, and life sciences majors. In this study, we did not systematically analyze data to determine whether the active-learning experiences of white men majoring in the life sciences differed from the rest of the participants. We did not employ a form of member checking in this study. However, we did intentionally craft our research team to include at least one or more researchers who identifies/identified as a STEM major with ADHD/SLD (see positionality statement in Supplemental File 1).

RESULTS

We interviewed 25 STEM majors with ADHD/SLD to determine how the implementation of active-learning practices affected their perceived learning experiences and self-advocacy in undergraduate STEM courses. In our study, "perceptions of learning" refers to how a participant thinks their own learning is affected by a particular teaching practice or classroom aspect. Throughout the *Results* we present both a figure and a table to portray similar information. The goal of this type of presentation is to provide readers the option of selecting the format that best suits their needs or preferences, which is in line with providing flexibility in the use of printed materials for our audience. In our figures and tables, we present participant quotes with the intention of centering the experiences of STEM students with ADHD/SLD. Participant quotes have been lightly edited for brevity and clarity. Brackets represent text added to enhance readability, and ellipses indicate text removed from the quote.

Aspects of Active Learning Influence Participant Perceptions of Learning

Participants described aspects of active learning that influenced their perceptions of learning in response to open-ended interview prompts. These interview prompts included: 1) "Walk me through what a typical day is like for you in your active-learning STEM course," 2) "Tell me about your interactions with your instructor," and 3) "Tell me about your interactions with your peers." Aspects of active learning that influenced participants' perceptions of learning included: environment, course structure, instructor reveals thinking, course materials, flipped courses, group work, and clickers. We begin by presenting the more general aspects of active learning that influenced our participants' perceptions of learning (i.e., environment and course structure) and then move into more specific aspects of active learning, for instance, group work and clickers. Aspects influencing participant perception of learning are summarized in Table 3 (see Supplemental File 5 for figure).

A definition of each aspect of active learning and a description of how the aspect influenced perceptions of learning are described in the following subsections. Perceptions of learning refers to how the participant described a particular aspect of active learning to affect their own acquisition of course content. Within each subsection, we describe how that aspect of active learning led to participant perceptions of supported or hindered learning. In our results, several active-learning aspects overlap. We decided to present these aspects separately, so that readers may readily identify a certain active-learning aspect of interest.

Environment. Environment encompassed the physical space of an active-learning STEM course and the way a participant perceived the classroom climate of the course. When functioning as a perceived support of learning, the environment encouraged participants to participate during the class, broke up lecture into more manageable blocks of information, offered opportunities for hands-on learning, and provided space to be distracted in class. Participants like Wren, Elliott, and Lena shared that they feel comfortable answering and asking questions during class within active-learning STEM courses. Additionally, several participants reported that active learning divided up lecture and offered them other ways to engage with material besides listening and taking notes, which supported their learning. Dylan, a participant with ADHD, especially valued active learning that provided opportunities for hands-on learning. Dylan described in-class activities as helpful when they allowed him to physically manipulate objects with his hands as opposed to completing worksheets on paper.

> Some activities can help, like the first activity helped out a lot. It was between primary, secondary, tertiary, and quaternary protein structure, and it was with phone cords. That helped a lot. But other [activities] can be challenging and then after you're kind of just like, what was the point of that?... I liked the phone cords because I had it in my hand.—Dylan

Participants like Brett explained that the environment of active-learning STEM courses also supports their learning, because there is built-in space for them to be distracted without missing vital information. Brett stated:

> With my ADHD, it's great to kind of be able to get some energy out. Distractions are there for everyone and you kind of can work through them easier than in a lecture where if you get distracted you miss stuff. So active learning is definitely a huge benefit for any STEM class.—Brett

While many participants found the environment of active-learning STEM courses to support their learning, there were ways in which the environment hindered their perceptions of learning. Stella shared that the multiple dry-erase boards present in a SCALE-UP–style room make it challenging for her to follow the instructor's explanation. She explained that the classroom setup is "strange," because there are multiple dry-erase boards that her instructor uses within a single class period.

> It's irritating because he'll be on one end of the room starting a problem, run over to the other end of the room, finish the problem ... Half of the class has to move to see what he's writing … He's just running back and forth. For me, with ADHD and stuff, it's better to just have it all in one spot. So I'm not missing half of what you're saying.—Stella

For participants like Stella, a more organized use of the dry-erase boards would support their perceptions of learning in a SCALE-UP–style room. Besides the physical layout of the classroom, participants reported that the pacing of their active-learning STEM course could hinder their learning. Many participants perceived the in-class activities as moving too quickly, whereas one participant shared that they felt the in-class activities moved too slowly.

Course Structure. Drawing on prior work (Eddy and Hogan, 2014), we considered how participants perceived course structure. Examples of course structure supplied by participants included graded preparatory assignments (e.g., frequent reading quizzes) and in-class engagement activities (e.g., clicker questions, worksheets, case studies). Some examples of in-class engagement activities, such as clicker questions and group work,

TABLE 3. Aspects of active learning influencing participants' perceptions of learning

Aspect of active learning	Supporting perceptions of learning	Hindering perceptions of learning
Clickers	Promote metacognition	Short-answer time limits Distracted by class short answers
Group work	Promotes metacognition Alternative sources of motivation Builds relationships to ask questions and form study groups	Peers do not want to work with me Potential for negative emotions Lack of clear directions
Flipped courses[a]	Flexibility in use Promotes metacognition Incentivizes attendance Breaks up lecture	Long videos Video misaligned with class Lack of instructor explanation Withdrawing from course
Course materials	Organization of content Flexibility in use	Extensive textbook reading Lack of screen reader
Instructor reveals thinking	Promotes metacognition Helps students apply content from worked examples	Lack of instructor explanation
Course structure	Incentivizes preparation Incentivizes attendance Frequent opportunities for practice	Overlooking accommodations Increased stress Challenging to prepare for
Environment	Encourages participation Breaks up lecture Opportunities for hands-on learning Space for distractions	Room is distracting Class moves too fast Class moves too slow

[a]The supports for flipped courses overlap with all other aspects of active learning functioning as a support. A few key supports for flipped courses are indicated in the table. See Supplemental File 5 for a figure version of this information.

are presented in our study as stand-alone themes due to the prominence of these aspects in our data. Overall, we found that course structure could be perceived to support participant learning, because it incentivized class preparation and attendance and provided opportunities to practice problems for upcoming exams. Although participants found course structure to support their learning, there were ways in which course structure hindered participants' perceptions of learning. Many participants found it challenging to prepare for the frequent assignments and class engagement activities. Often, these challenges were related to issues with course materials and flipped courses, which we describe in the following subsections. Participants also shared that their instructors often overlooked their accommodations on the assignments and quizzes that were part of their active-learning course's structure. Because we only interviewed students, we do not know whether instructors intentionally overlooked these accommodations, were unaware that these accommodations were needed, or forgot to set up these accommodations for students. Participants in this study typically used extra time accommodations for exams and quizzes, and some participants used a note-taking accommodation. We detail in a later section how overlooking accommodations in active-learning STEM courses affected participants' self-advocacy.

Instructor Reveals Thinking. Instructor reveals thinking encompassed instances when participants discussed the instructor or teaching assistants demonstrating or explaining course content in active-learning STEM courses. The instructors often revealed their expert thinking through worked examples, after clicker questions, or by answering participant questions individually during class time. When the instructor shared their expert thinking, participants perceived it to support their learning. Our data suggest that a lack of instructor explanation, or when the instructors failed to reveal their own thinking, had a negative impact on participants' perceptions of learning. This view was most prominent for Kacey, who shared her frustration regarding an active-learning STEM course. She explained that her instructor failed to discuss why certain clicker question answers were correct or incorrect. Kacey stated:

> I don't understand how you could call this a class, when they're just throwing this stuff at you, but they're not helping you understand it, and they're not going back and saying, "This is wrong because of this, and this is how you do it the right way, because X, Y and Z." I got none of that from [my instructor], and so I learned all my stuff from [a third-party tutoring service].—Kacey

Kacey's dissatisfaction when the instructor failed to reveal their own thinking was shared by Thomas. Thomas stated that when his instructor does not explain the content or the purpose of an activity before starting group work, he doesn't understand "what the hell's going on." This made active learning challenging, because Thomas was unsure of what he was supposed to learn and what he needed to accomplish during the class period. In this type of situation, a student may feel lost or incapable, because they do not understand the expectations and objectives for the class period, which can make it challenging to communicate with their group mates. These issues can, in turn, lead to the student being excluded from the group.

Course Materials. Course materials comprised media and other tools, such as note-taking guides, provided by the instructor with the presumed purpose of supporting student learning of class content. Participants discussed how course materials such as videos supported their learning by promoting organization of content and flexibility in use by the student. Lena, a participant with ADHD, explained how the videos provided by the instructor supported her learning in a STEM course.

> I'll be watching it, but I have to rewind because I'm not paying attention, so I like that because you can't do that in real life … The class was still hard, but I think I would have failed that class if that wasn't a thing.—Lena

Another participant, Wren, who qualifies for a note-taking accommodation due to ADHD, described that the interactive note-taking guide provided by her calculus instructor supported her learning. The interactive note-taking guide was helpful for her, because it supported organization of class material and created a resource that she could access while solving practice problems.

> We were actively engaged when he was lecturing. We had the packet to refer to when we were [solving problems] that were like notes, but notes that made sense and we didn't have to waste time writing down, like, oh, it's this theory … [The notes] made a lot more sense. I really excelled when I had that type of resource.—Wren

While course materials supported the learning of many participants, other participants explained that some course materials did not support their learning. A common issue was difficulty reading from the textbook, which affected a participant's ability to prepare for in-class activities. Vivian, who has a specific learning disorder, expounded on this by saying:

> It's hard for me to read something without being exposed to it before. So if I just read about a topic, then I really don't grasp it at all. I prefer to read after the class. So in classes that they don't want you to do that, it's really hard for me.—Vivian

Vivian and other participants explained that when the textbook and other materials are inaccessible to them, active learning can be a very negative experience. Reading materials may be inaccessible to students when a student qualifies for an audio version of the textbook, but they do not have or are not able to use this technology for a variety of reasons. We also considered the textbook to be inaccessible to students when the sheer volume (e.g., 80–100 pages) of required reading for a single class period is not feasible for them to complete when taking multiple classes at the same time in a short window of time. Many of the supports and barriers associated with course materials were also applicable to flipped courses.

Flipped Courses. A flipped course is a type of class in which students are introduced to material outside the formal class period before coming to class. During class, opportunities for applying and practicing the materials are provided that often involve additional active-learning practices (group work, clickers, etc.). Flipped courses are considered by some researchers to be a form of active learning and were discussed by many participants as an active-learning practice (Lombardi and Shipley, 2021). We found that flipped courses supported participant perceptions of learning in the same ways described for other aspects. However, we present flipped courses as a stand-alone aspect of active learning, because flipped courses represented the most profound active-learning barrier reported by our participants. Many of our participants perceived that they were expected by their instructors to learn material individually, as opposed to just becoming familiar with terminology or basic concepts outside class, before the next session. Two participants, Bryce and Penny, reported deciding to withdraw from a flipped course, which ultimately altered their plans to complete their degrees. Bryce, a student who qualifies for alternative textbooks (an audio version of the textbook) explained that, at this particular time, he was not yet able to access his accommodations, because he was in the process of being re-evaluated in order to provide official documentation of his disability to the university's DRC.

> The reason I [withdrew from a flipped STEM course] was hugely in part due to the "flipped" classroom setting. Basically, it was 80–100 pages of reading in between classes in the textbook. And, that was, essentially, how you were supposed to teach yourself the course. In terms of what we actually did in class, I was amazed. There was no lecture component to the course whatsoever. You would walk into the course, you would sit down, and then immediately at the start of the course, you would start answering the clicker questions. And, after each question, there was no explanation of why that was the answer … It was just, "Let's move on to the next question." … When I was doing the reading, I wasn't pulling all the information in, just because there was so much of it. And, therefore, I was struggling on these questions in class. And, I had no lecture, no component to it where I was getting taught the information. I struggled so much that I felt there was no way I was gonna succeed. And, that was the main reason I dropped out. So, I'm not looking forward to retaking that course.—Bryce

Bryce's negative experience with flipped courses was reiterated by Penny. Penny was a participant with both ADHD and SLD who stated,

> I withdrew from [a flipped STEM course] because it was really bad. [The instructor's] videos that he would make were really unhelpful. He would give very simple examples and then in class he would give us extremely hard problems, and they just weren't helpful at all.—Penny

Other participants described difficulties in flipped courses, as well. Lena shared that at first it was challenging for her to learn how to prepare for her flipped STEM course:

> It was kind of a weird adjustment at first, because I'm not used to getting YouTube, like, videos sent to me, so it was kind of like you had to pace yourself and watch it right at the right time.—Lena

Lena explained that she can struggle to schedule and plan her work as part of her disability, which influenced her timing of class preparation. Felix, a participant with ADHD and a specific learning disorder, explained that he struggled to pay attention to videos. Felix explained, "When the video lectures that you watch at home aren't very engaging, I do not pay attention to them at all. I just can't make it through them." Later in the interview, Felix shared that, because he struggles to watch the videos, he comes to class unprepared, which has a negative impact on his experiences in group work.

> [The thing] I didn't really like so much about the flipped classroom thing was if you had fallen behind on lectures or homework, it just made me feel uncomfortable to struggle through questions working with other people.—Felix

Felix's data represent one example of how issues with flipped courses relate to other active-learning practices, such as group work.

Group Work. We defined group work as instances when students described working with their peers to complete a task or assignment. Group work supported participant perceptions of learning by providing immediate feedback about course content, which supported metacognition by helping participants identify what they know and what they may need to continue studying. Group work further supported participant perceptions of learning by providing alternative sources of instruction and motivation for learning. Several participants stated that they found group work valuable, because their peers would explain concepts at a level they could more easily understand compared with how their instructor explained concepts. Carson, an upper-division student with both ADHD and SLD, shared that he no longer feels motivated to learn in his courses by his own grades. He explained how group work provided him with a different motivation to learn:

> I think [group work] engages me more because I work best when I'm helping other people. Because if it's just, like, about me, and, like, my grade, I have a hard time motivating myself to, like, get straight As. There's a bunch of different reasons for that. But if I have to work with someone on a problem, then it feels more real, … It motivates me to, like, learn the material, because I enjoy explaining things that I understand.—Carson

Group work also supported our participants' perceptions of learning by fostering peer-to-peer connections. Participants described that they could ask their peers questions about topics they found challenging and that they could form study groups because of group work in class. Peer-to-peer connections are also likely a support because they provide a mechanism to fill gaps, a self-advocacy behavior (Pfeifer *et al.*, 2020).

Several components related to group work were perceived to hinder the learning of our participants. These barriers included instances when peers did not want to work with the participant, because the participant was thought to work more slowly than the class. Lena, who is an upper-division engineering student, stated:

> Engineers tend to be very impatient. So if you're not up to speed with them, they'll just not work with you anymore … If they did [work with me], active learning would probably be ten times better.—Lena

Other participants explained that group work can create the potential for them to experience negative emotions during class, such as embarrassment. Jack, a student with a specific learning disorder in reading, reported:

> I wish they would understand why I never like reading in groups like out loud reading or why I don't like writing by hand in front of them…. If they knew why I was struggling, it'd be better than them just thinking I was [not capable].—Jack

Other participants like Erik shared this sentiment. Erik explained that, as someone with a specific learning disorder in writing, he feels especially uncomfortable being asked to hand-draw graphs in front of his peers. Moreover, group work can be a time in which participants will have to reveal their use of accommodations or discuss their disability with their peers. Zara shared that she discussed why she uses extended-time accommodations when her peers noticed she received extra time for quizzes.

> It was brought up, because we did group quizzes and I got longer time on a group quiz and they go, like, "Why do you get longer time?"—Zara

Zara was a participant who felt comfortable explaining to her peers why she used accommodations. However, many of our participants were not comfortable talking about their disability or accommodations with their peers. We anticipate that if these participants were in a group exam situation, similar to what Zara described, they would feel highly uncomfortable. Finally, participants reported that a lack of clear directions or expectations for group work from the instructor hinders their perceptions of learning. Participants shared that they feel frustrated when the instructor does not provide clear directions for group work.

Clickers. Clickers are student response systems that allow students to anonymously share their answers to instructor questions. Answering clicker questions supported the metacognition of our participants by prompting them to monitor their own understanding of class content. Participants described especially valuing the instructor's explanation of why each answer option was correct or incorrect. However, some implementation of clicker questions within STEM courses was problematic for participants, notably when clicker question responses required them to compose short answers within a limited amount of time. Josiah, a participant with a specific learning disorder in reading, and Stewart, a participant with ADHD, explained that they felt they needed more time to type their answers than provided by the instructor. This was especially concerning for Stewart, because his clicker questions were graded for accuracy in one of his classes. Other participants, like Kacey, explained that viewing the class responses to free-response clicker questions is particularly stressful for her due to differences in formatting.

> With [free-response clicker questions] the technology is weird … Some people do the [answers] in all capital letters, some people do them in all lowercase letters. Some people do them in both kinds of letters. Some people put in commas, some people don't. That's so stressful for me. It's not organized in [any] way.—Kacey

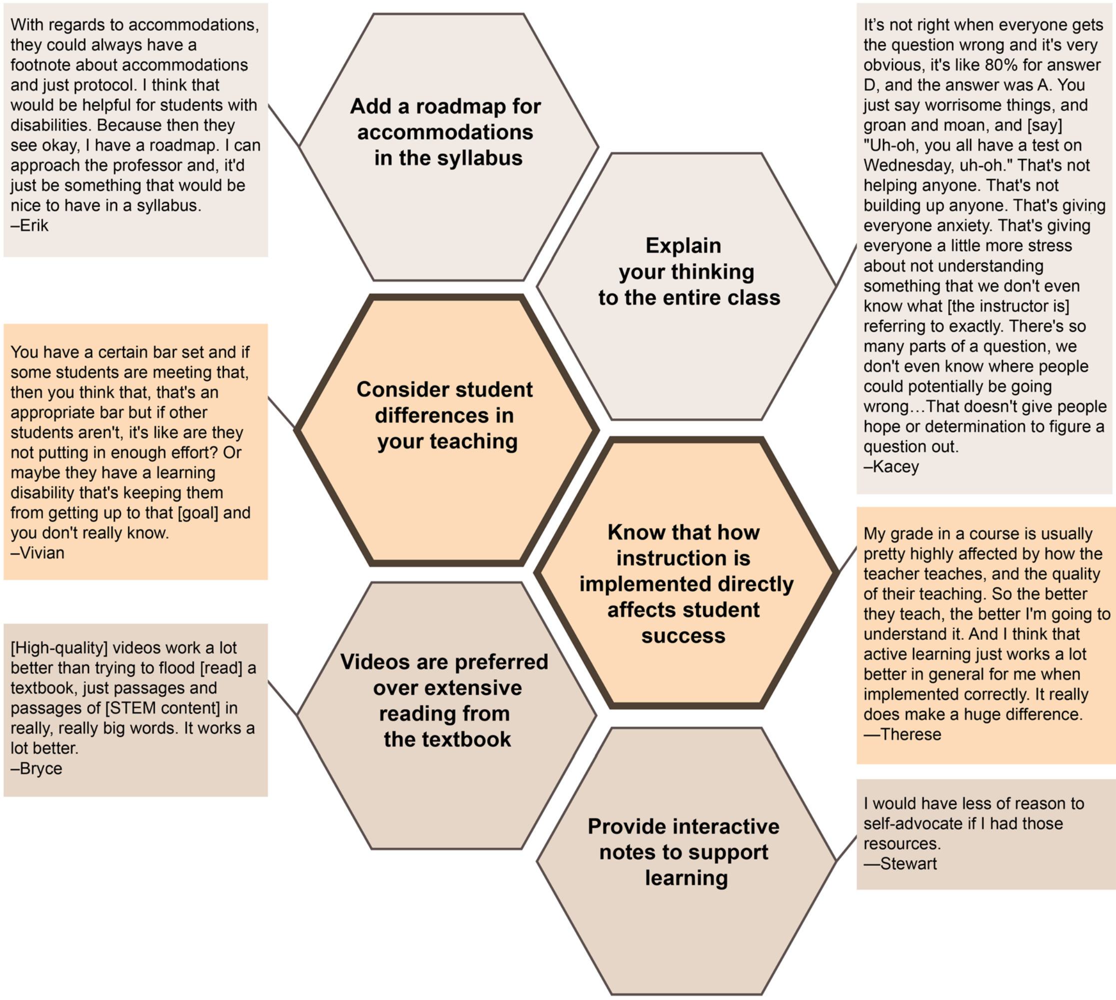

FIGURE 1. **Participant suggestions for STEM instructors of active-learning STEM courses. Orange represents more general suggestions, and shades of tan indicate more specific suggestions related to barriers presented in this study. These quotes are also provided in a table in Supplemental File 6.**

Some participants with ADHD shared that the way information is organized affects their learning, because they will attend to details their instructor does not consider to be important, but these nonessential details seem and feel very important to the participant. This results in situations where the participant is spending time making sense of these nonessential details on their own, which can detract from learning what their instructors consider to be essential details, leading to stress. Kacey and other participants expressed a strong preference for clicker questions with multiple-choice responses that are aggregated automatically by the clicker's software program. They found this format less distracting, and they could focus on the content of the question and the submitted responses as opposed to the formatting differences of the answers submitted by the entire class.

Participant Suggestions for STEM Instructors about Active Learning

Participants shared what they wished STEM instructors knew about their experiences in active-learning STEM courses during the interview. Quotes for each point are provided in Figure 1 (and in a table in Supplemental File 6). We organized their feedback into major points STEM instructors should be aware of when they incorporate active-learning practices into their courses. We encourage readers to reflect upon these quotes, which we used as the basis for the recommendations in the *Implications for Teaching* section in the *Discussion*.

The Influence of Active Learning on Self-Advocacy

We asked participants if their self-advocacy changed as a result of being enrolled in a STEM course that incorporated aspects of active learning. Participants shared a diversity of responses to this question, which are summarized in Figure 2 (and in a table in Supplemental File 7). Broadly, there were two main groups of participants: those who did not think their self-advocacy changed, and those who thought their self-advocacy changed in response to aspects of active learning. For participants who reported that their self-advocacy did not change, there were two distinct reasons. The first reason involved how the participant viewed their accommodations. These participants reported that their self-advocacy did not change as a result of active learning, because their accommodations should always be sufficient for them. This view was illustrated by Sadie, who said:

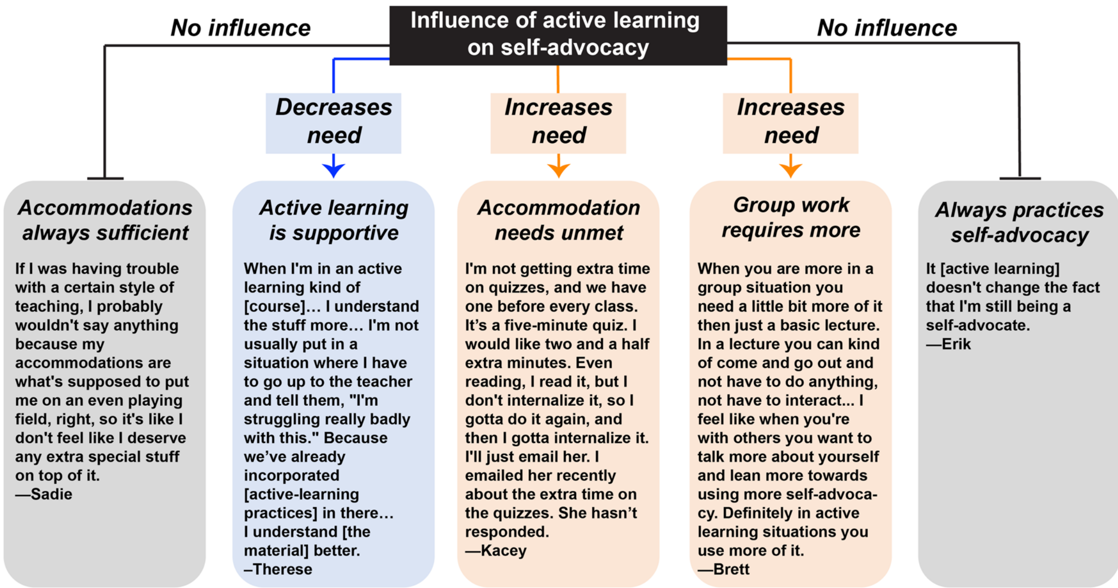

FIGURE 2. The influence of active learning on self-advocacy. Participants explained that they saw active learning as exerting no influence (gray) on their self-advocacy, or that they considered active learning to influence their self-advocacy (blue and orange). Blue represents a decreased need for self-advocacy, while orange represents an increased need for self-advocacy. These quotes are also provided in a table in Supplemental File 7.

> If I was having trouble with a certain style of teaching, I probably wouldn't say anything because my accommodations are what's supposed to put me on an even playing field, right, so it's like I don't feel like I deserve any extra special stuff on top of it.—Sadie

Here, Sadie's notion of self-advocacy is equated with only the use of accommodations. She did not consider it appropriate for her to communicate with the instructor if there are aspects of the course that may not support her learning. Other participants shared that active learning does not influence their self-advocacy, because they are positioned to self-advocate in all course types. In other words, these participants would engage in self-advocacy at the same level in all their courses regardless of whether a course was active learning or a lecture. Erik articulated this view. "It [active learning] doesn't change the fact that I'm still being a self-advocate."

Although some participants did not view aspects of active learning as influencing their self-advocacy, many participants did. A handful of participants stated that they perceive aspects of active learning to decrease their need for self-advocacy. These participants tended to find active learning to be supportive of their learning. For example, Therese stated,

> When I'm in an active learning kind of [course] … I understand the stuff more … I'm not usually put in a situation where I have to go up to the teacher and tell them, "I'm struggling really badly with this." Because we've already incorporated [active-learning practices] in there … I understand [the material] better.—Therese

Therese saw active learning as providing her with more opportunities to learn the course material as opposed to lecture-only STEM courses, which ultimately decreased her need for self-advocacy.

Some participants reported that their need for self-advocacy increases largely due to the issue of overlooking accommodations in active-learning STEM courses. This often occurred for enactments of course structure (i.e., preclass reading quizzes and pop quizzes administered in class) and when clicker questions required short answers and were graded for accuracy. Kacey shared her experience trying to use her extra time accommodations on preclass reading quizzes that are graded for accuracy:

> I'm not getting extra time [for] quizzes, and we have one before every class. It's a five-minute quiz. I would like two and a half extra minutes. Even reading, I read it, but I don't internalize it, so I gotta do it again, and then I gotta internalize it. I'll just email her. I emailed her recently about the extra time on the quizzes. She hasn't responded.—Kacey

Kacey is engaging in self-advocacy in this example. She is communicating with her instructor to request the use of extra time on the reading quizzes in her active-learning STEM course. Due to a lack of instructor response, Kacey is not able to access her accommodation, which is likely affecting her performance on reading quizzes in this class. Lack of access to accommodations could affect her overall success in the course.

Other participants described that they perceive their need for self-advocacy to increase because of group work, an aspect of active learning. Brett, a participant with ADHD, expanded on this notion.

> When you are more in a group situation you need a little bit more of it [self-advocacy] then just a basic lecture. In a lecture you can kind of come and go out and not have to do anything, not have to interact … I feel like when you're with others you want to talk more about yourself and lean more towards using

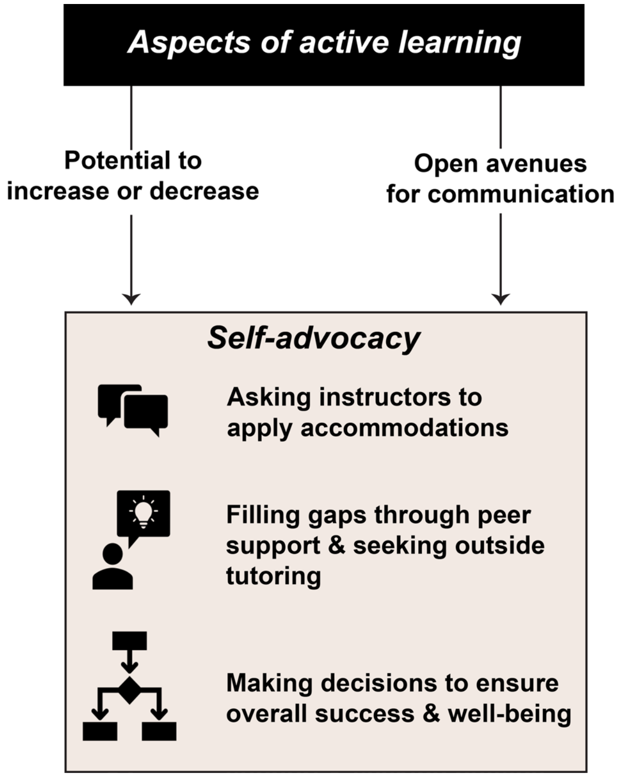

FIGURE 3. Summary describing how aspects of active learning influence self-advocacy for students with ADHD/SLD in our study. The tan box includes the examples of self-advocacy reported in our study: asking the instructor to apply accommodations, filling gaps through peer support and by seeking outside tutoring, and making decisions to ensure overall success and well-being.

> more self-advocacy. Definitely in active-learning situations you use more of it.—Brett

While some participants perceived active learning to increase their need for self-advocacy, many of these participants explained that, although there may be an increased need for self-advocacy, they feel more comfortable communicating with the instructor. Communication is an essential component of self-advocacy (Test *et al.*, 2005; Pfeifer *et al.*, 2020). Participants attributed enhanced comfort to communicate with the instructor to the environment of their STEM courses that incorporate active-learning practices. Stella reported,

> When the teachers are walking around and stuff, that gives you the opportunity to ask more questions if you need it. It's not all 100% the student going to the teacher, but more of this, this kind of equality.—Stella

Lena shared a similar sentiment and noted that she feels more comfortable communicating with instructors in active-learning STEM courses, because her peers are less likely to notice her talking to the instructor. Lena was a participant very concerned about the prospect of her peers learning she has a disability and qualifies for accommodations. Overall, we found that aspects of active learning could influence the self-advocacy of our participants in two ways (Figure 3). One, active learning had the potential to affect the need for a participant to engage in self-advocacy. Two, active learning could open avenues for communication with the instructor, which enabled self-advocacy.

Examples of Self-Advocacy. During the interview, participants shared examples of self-advocacy in the context of an active-learning STEM course. These examples are summarized in Figure 3. Participants described asking the instructor to apply their extended-time testing accommodations to quizzes and clicker questions. Our participants also explained that they would fill gaps, a self-advocacy behavior, by asking peers from their group to explain challenging topics to them and, in some cases, tutor them. Participants further filled gaps by seeking third-party tutoring when they found their active-learning STEM course did not support their knowledge acquisition. Participants also used their self-advocacy knowledge and beliefs to make difficult decisions about withdrawing (or not) from a particular active-learning STEM course. For example, some participants described that they ultimately decided to withdraw from an active-learning STEM course because they did not see a way for them to pass the course due to how active learning was implemented. We see the decision to withdraw from a course as a manifestation of self-advocacy. Participants applied their knowledge of self, knowledge of rights, and agency to enact a behavior that they perceived would support their overall well-being and permit their future success. We acknowledge that withdrawing from a course may have the potential for negative long-term effects in terms of timelines for graduation. However, we consider this decision to be our participants' responses to an environment that was not designed with them in mind.

DISCUSSION

We interviewed 25 STEM majors with ADHD/SLD to characterize how active-learning practices in undergraduate STEM courses influenced their perceptions of learning and self-advocacy. Here, we connect our results to the existing literature related to students with disabilities and active learning. We close by providing a list of implications for research and teaching.

The Influence of Active Learning on Perceptions of Learning

Our results establish that there are enactments of active learning that our participants perceive to hinder their learning. We call these enactments "active-learning barriers." Some of these active-learning barriers are previously characterized. Students with SLD in reading are known to experience difficulty with the amount of textbook reading required in college courses (e.g., Hadley, 2006). Additionally, SCALE-UP–inspired classrooms can be distracting for some students with ADHD (James *et al.*, 2020). Interviews with DRC directors revealed that students with ADHD/SLD may not receive enough time to complete clicker questions and that students with ADHD/SLD can experience difficulty working in groups (Gin *et al.*, 2020). In our study, some students with ADHD/SLD described active-learning classes to be stressful, which tracks with existing active-learning research for students more broadly (England *et al.*, 2017;

Cooper *et al.*, 2018; Brigati *et al.*, 2020; Downing *et al.*, 2020; Hood *et al.*, 2021). While some of the barriers noted in our study were previously known, we did identify a previously uncharacterized active-learning barrier for students with ADHD/SLD. This barrier involved how student responses to clicker questions are compiled for class discussion. When students submitted short-answer responses to clicker questions that the entire class could view, participants described being distracted and stressed by the formatting differences in the displayed answers.

There is clear evidence from our study that active-learning practices can be perceived to support participant learning. Our study and a study in introductory physics found that participants with ADHD perceived active-learning classes as providing "space for distractions" (James *et al.*, 2020, p. 16). Many of the active-learning supports identified in our study are consistent with the recognized benefits of active learning. For example, clicker questions and group work were valued, because they informed our participants' metacognition by helping them to monitor their own understanding of class content. Senior-level biology students reported that group work provides opportunities to monitor their own understanding of class content, and group work can prompt students to explain their reasoning to themselves and their peers (Wilson *et al.*, 2018; Stanton *et al.*, 2019). Because we only interviewed students with ADHD/SLD, we did not determine how the supports named in our study compare with the supports that may be identified by students without ADHD/SLD. We hypothesize that some of the active-learning supports described in our study may be of greater importance for students with ADHD/SLD. For example, students with ADHD/SLD may be more likely than students without ADHD/SLD to report benefiting from well-designed videos in flipped courses because of the ability to rewatch videos as needed during their learning process. Future research is needed to determine whether this and similar hypotheses are supported.

We found that a single active-learning practice could function as a support or as a barrier for our participants. From this finding, a question emerges: How can the same active-learning practice support learning in some cases, but hinder learning in other cases? We begin to address this question by discussing two instruction-related issues: implementation of an active-learning practice and universal design for learning.

Implementation Issues Contribute to Formation of Active-Learning Barriers for Students with ADHD/SLD

Many of the barriers reported by our participants appear to arise from how a particular active-learning practice is implemented. For instance, both Bryce and Penny explained that they withdrew from flipped courses. In Bryce's case, this flipped course included extensive readings from an inaccessible textbook and a lack of instructor explanation following clicker questions. Research regarding flipped courses shows that videos led to enhanced student performance compared with textbook reading (Jensen *et al.*, 2018; Pulukuri and Abrams, 2021). We note that these studies, and many others, do not report disability-related demographics of participants. In general, we presume that there are likely some students with disabilities represented in these samples. For Penny, it appeared that the instructor's videos were not following established best practices for the creation of educational videos (Brame, 2016). She shared that videos in this flipped class felt disconnected from what they were doing in class, which suggests that the videos were not created by the instructor with relevance to the course in mind (Brame, 2016). Our participants also described an active-learning barrier when the instructor fails to explain why clicker question responses are correct or incorrect. Previous research regarding the use of clicker questions shows that providing students with a combination of peer discussion and instructor explanation improves student performance (Smith *et al.*, 2011).

Overall, our data suggest that how an active-learning strategy is implemented, as opposed to the particular strategy itself, has the potential to impart severe academic consequences for students with ADHD/SLD. This is concerning, and something that, as a community, we should take steps to address. From our perspective, highly negative experiences with active learning could lead an individual student with ADHD/SLD to attribute these challenging experiences to their disability as opposed to the way the active-learning practice was implemented. Attributing their struggles to their disability may cause decreased self-efficacy, which could affect their success in future STEM courses. Additionally, students with highly negative active-learning experiences may decide to avoid all active-learning courses in the future. Opting out of active-learning STEM courses may be best for some students. Yet we note that many of our participants reported their overall learning to be best supported in active-learning STEM courses when practices were well implemented.

Universal Design for Learning in an Active-Learning Context

Based on our results, one way to enhance STEM active-learning experiences for students with ADHD/SLD is to consider using universal design for learning. Universal design for learning is a framework of three guiding principles (CAST, 2018). The three guiding principles of universal design for learning are to provide (1) multiple means of engagement, (2) multiple means of representation, and (3) multiple means of action and expression. Universal design for learning was originally developed to create more accessible classrooms for students with disabilities in K–12 (Jimenez *et al.*, 2007). Universal design for learning is considered helpful for many students, not only students with disabilities (CAST, 2018). Yet more research is needed to fully understand how UDL can be implemented to meet the needs of diverse groups of students, including students with and without disabilities (e.g., Boysen, 2021). Previous studies of undergraduate STEM curricula and courses show that the adoption of universal design for learning is limited (Scanlon *et al.*, 2018a,b; Schreffler *et al.*, 2019). Our results are consistent with this finding. Active learning could function as a barrier when participants were required to complete extensive textbook reading to prepare for class. Because there was only a single source of media, this practice violates the universal design for learning guideline of providing multiple means of representation. If only a textbook is provided, students who may experience difficulty reading efficiently are disadvantaged when it comes to class preparation, which can negatively affect their experiences working with peers.

Intriguingly, many of the ways in which active-learning practices were perceived to support perceptions of learning aligned with principles of universal design for learning. For example, Carson explained that group work helps him feel motivated to learn the material because he is no longer interested in earning straight "A's" in his STEM courses. Group work for Carson seemed to align with the guiding principle of multiple means of engagement. In the future, exploring how universal design for learning and active learning relate to one another may help refine our understanding of these broad educational constructs.

Implications for Research

Disability is part of the human experience, but much of the existing higher education research ignores disability as a possible feature of the student experience (Peña, 2014). There is a need to consider the experiences of students with disabilities within future active-learning research. Our results are related to issues of fidelity of implementation. Fidelity of implementation is defined as "the extent to which the critical components of an intended educational program, curriculum, or instructional practice are present when that program, curriculum, or practice is enacted" (Stains and Vickrey, 2017, p. 2). The way in which instructors "in the wild" implement a particular instructional practice can differ from the implementation intended by the developers of the practice (Dancy *et al.*, 2016; Stains and Vickrey, 2017; Offerdahl *et al.*, 2018). In the context of STEM education, fidelity of implementation can be obstructed when a particular instructional strategy is enacted in a manner that neglects the critical components or essential elements of that practice (Offerdahl *et al.*, 2018). Yet defining the critical components of a particular active-learning practice is often not straightforward (Eddy *et al.*, 2015). For example, many active-learning practices do not have a single developer, nor are the active-learning practices consistently defined within the existing literature (Waugh and Andrews, 2020). This may make it challenging for STEM instructors to readily identify how they should implement a particular active-learning practice and whether that practice is appropriate within their own teaching contexts (Eddy *et al.*, 2015; Waugh and Andrews, 2020). We recommend that, as the field begins to theorize and conduct fidelity of implementation evaluations of existing evidence-based instructional practices, students with disabilities be included in these research efforts. We see opportunities to systematically characterize how instructional practices affect students with disabilities within the qualitative arm of fidelity of implementation evaluations (Stains and Vickrey, 2017). By consciously including students with disabilities in future research efforts and in fidelity of implementation evaluations, we may be better positioned to understand how instructional practices are affecting the experiences of students with disabilities in undergraduate STEM courses.

In this study, we did not investigate in depth how assessment practices for course exams within active-learning STEM courses influence student experiences. For instance, in some active-learning STEM courses, two-stage collaborative exams may be used that consist of an individual exam portion, followed by a group exam portion (e.g., Leight *et al.*, 2012; Cooke *et al.*, 2019). To our knowledge, how students using accommodations are affected by these two-stage collaborative exams is not yet known. Previous research shows that students using accommodations can feel singled out when they perceive their peers are aware that they use accommodations for exams (Nieminen and Pesonen, 2022; Pfeifer *et al.*, 2021). Some students reported that they, at times, would decide not to use accommodations for exams in their STEM courses to avoid inadvertently revealing their disability status to their peers (Pfeifer *et al.*, 2021). Future research should examine how assessment practices surrounding course exams in active-learning STEM courses affect the experiences of students with ADHD/SLD.

Implications for Teaching

Our study offers evidence that implementation of a particular instructional practice can result in negative experiences for students with ADHD/SLD in active-learning STEM courses. As instructors, we have a responsibility to consider how students may be affected by the implementation of a particular active-learning practice. We encourage readers to consult existing evidence-based teaching guides offered by *CBE-LSE*, such as the guide on group work (Wilson *et al.*, 2018), as well as other resources like the Practical Observation Rubric to Assess Active Learning (Eddy *et al.*, 2015), and to share these resources with their colleagues to support more-inclusive, and likely effective, implementation of active-learning practices. The language we use to talk about teaching matters. Taking time to clarify active-learning terminology and the essential elements of a teaching practice when discussing instruction may be one step toward promoting more effective implementation of that practice within our departments (Dancy *et al.*, 2016). Enhancing the implementation of active-learning practices could better support the learning of students with ADHD/SLD in undergraduate STEM courses.

Participants shared suggestions, including teaching recommendations, that they perceived would enhance their own experiences of learning in STEM courses using active-learning practices (Figure 1). We discuss these suggestions in more detail here.

- **Consider student differences in your teaching.** Many participants explained that they find it frustrating when instructors assume that they are lazy or have not put in the effort to reach a certain learning goal set forth by the instructor. Vivian's quote in Figure 1 highlights that she wishes her instructors knew that she was putting in a lot of effort into her course work, but that sometimes her learning disability makes it challenging for her to meet the learning goals.
- **Know that how instruction is implemented directly affects participant success in a course.** Some participants in our study explained that they perceive themselves to be especially affected by how a STEM instructor teaches a STEM course. Therese spoke to this idea in her quote in Figure 1.
- **Explain your expert thinking to the entire class.** Our participants shared that hearing the instructor's explanation is helpful for clicker questions, worked examples, and for more general directions to the class. A lack of instructor explanation was a major barrier for our participants' learning. Often, when the instructor failed to reveal their own thinking to the

class, participants would describe making decisions to seek third-party tutoring or to withdraw from the course. Kacey described why this type of situation is a negative influence on her perception of learning, in the context of clicker questions (Figure 1).

- **Provide interactive notes to support learning.** Our participants described how instructor-provided interactive notes were a major support for their learning. Some of our participants described that, when an instructor is lecturing, the lecture can seem like disconnected thoughts or random words. When this happens, it can be difficult to identify key information to write in their notes. As a result, students may write in their notes irrelevant information that the instructor shares tangentially. This is problematic, because the student may then use valuable time to study this irrelevant information. A few participants also shared that they may lose focus during class. When they regain focus, they are not aware of what information they have missed in the class. Providing interactive notes may help students to see where the class is now and identify what content they may need to follow up on. Additionally, some of our participants had SLD in writing, which can make note-taking difficult.

As we reported previously, nearly all participants in our study who qualified for a note-taking accommodation explained that they had difficulty using this accommodation (Pfeifer *et al.*, 2020). Some of the difficulties associated with note-taking accommodations were receiving low-quality notes or not receiving notes at all from the assigned note-taker. Given these difficulties in using a note-taking accommodation, participants expressed that they would prefer to take their own notes if possible. Providing interactive notes as a resource may allow students with ADHD/SLD to take more effective notes independently. Stewart explained that this type of resource would decrease his need for self-advocacy in his STEM courses (Figure 1).

- **Videos are preferred over extensive reading from the textbook.** One of the most profound barriers experienced by our participants was challenges in completing extensive readings required for flipped courses or in-class engagement activities. Our participants tended to favor well-designed videos to learn course content. Bryce, a student who qualifies for alternative textbooks, discussed this more in his quote in Figure 1. Participants also appreciated videos that were well aligned to the course, because they could easily revisit the video to clarify course material.
- **Add a road map for accommodations in the syllabus.** With implementation of active-learning practices comes questions about how accommodations will be administered within a STEM course (Gin *et al.*, 2020). One of our participants, Erik, suggested that instructors provide directions for how accommodations are implemented within an active-learning STEM course that go beyond the general disability statement often seen in syllabi (Figure 1). Most disability statements found in syllabi are the statements provided by campus DRCs. These generic statements direct students who plan to request accommodations to contact the DRC and provide contact information for the DRC. Frequently, these statements do not provide more directions about the protocols the instructor uses to administer accommodations in the course. For instance, students must engage in additional communication (an example of a self-advocacy behavior) with their instructors to determine whether an instructor prefers students take their exams at the DRC or plans to administer extra time accommodations in the class. Students also must communicate with their instructors to learn how they can use their extended-time accommodations for quizzes administered during class. Providing detailed accommodation practices in the syllabus may help students plan for accommodations. Alternatively, if instructors do not wish to include these protocols widely in the syllabus, having a prepared statement ready to share with students using accommodations could also serve a similar purpose.

We generated a comprehensive list of these recommendations from participants and our own recommendations (Table 4). Our researcher-generated recommendations were developed in response to the barriers and supports described by participants and, as appropriate, draw on existing suggestions from the literature. These recommendations are offered so that instructors can work to address the needs of students with ADHD/SLD in active-learning STEM courses. These recommendations may help support STEM instructors in developing more awareness of teaching practices that will better meet the needs of students with ADHD/SLD in their courses. We encourage instructors to view recommended inclusion practices as dynamic and not static, nor simply a checklist that will ensure a fully accessible course. It is important to remain flexible in these practices to support student perceptions of learning. Understanding when and how to be flexible will require instructors to develop a deeper awareness of student experiences of disability that can be informed, in part, through current and future research investigating the experiences of students with disabilities. Instructors should remain open-minded and willing to consider and respond to the feedback from students with disabilities about how course design can be enhanced to better support their perceptions of learning. Students with disabilities represent a sizable population in our classrooms, and enhancing their experiences in STEM will require a reflexive teaching practice that responds to feedback from students with disabilities.

CONCLUSION

We characterized how the implementation of active-learning practices in undergraduate STEM courses affects the perceived learning experiences and self-advocacy of students with ADHD/SLD. Our participants explained how aspects of active learning supported their perceptions of learning. However, we found many examples of how active-learning practices are perceived to hinder individual learning. Understanding these barriers can help STEM instructors become more aware of the potential pitfalls of active learning. Participants also discussed how active learning affected their self-advocacy and shared examples of how they practice self-advocacy in active-learning STEM courses. Our results offer future directions to create more-inclusive active-learning STEM courses in which self-advocacy is better supported. The development of more-inclusive active-learning STEM courses is likely to support the retention of STEM

TABLE 4. Suggestions for STEM instructors[a]

Aspect of active learning	Suggestion
General	**Consider student differences in your teaching**. Across our studies, participants shared that they wanted their STEM instructors to be more aware of how ADHD and SLD can affect their experiences in STEM courses (Pfeifer *et al.*, 2020, 2021). See *Discussion* for more information. **Know that how instruction is implemented directly affects participant success in a course**. Several participants describe that active learning can be a significant support for their learning, if implemented appropriately. We encourage instructors to consult existing resources when incorporating active-learning strategies into their courses, for example, the *CBE-LSE Evidence-Based Teaching Guides*. **Add a road map for accommodations in the syllabus**. See *Discussion* for more description. Conduct access check-ins regularly with your class to determine what students need in order to do their best work (Sins Invalid, 2019; Reinholz and Ridgway, 2021). Reinholz and Ridgway (2021) provide directions and several examples of how these types of check-ins can be incorporated into undergraduate STEM courses. Review the checkpoints from the universal design for learning framework and incorporate them into the design of the course. As a starting point, we encourage instructors to review the guidelines and checkpoints within the principle called “providing multiple means of representation” (CAST, 2018). Find ways to include “hands-on” learning opportunities for students when possible. For example, students can benefit from manipulating 3D printed models of complex structures. Participants in our study appeared to especially value these types of in-class engagement activities over more abstract, paper-based activities.
Group work	Provide clear expectations for group work and clear learning objectives for group assignments. Offer options for students to opt out of a specific group role. For example, students who do not feel comfortable reading or writing in front of their peers could select a different role in their group if given the choice. Communicate the expectation that all group members should be included and establish a mechanism to ensure that all students are included in group work. This could look like frequent instructor check-ins to make sure students are included in their groups. Wilson *et al.* (2018) suggest that using reward structures (e.g., shared grades or certificates of recognition for reaching a specific goal) can incentivize students to work together.
Clickers	Avoid displaying short-answer responses from the entire class. Avoid assigning short-answer clicker questions that are graded for accuracy, especially with strict time limits, or as suggested by Gin *et al.* (2020), offer students the option to submit their responses before or after class. Select clicker software programs that aggregate student responses. The volume of free-response text answers can be distracting to students, because it can be challenging to focus on the content of the answers as opposed to the way the answers are formatted. **Explain your expert thinking to the entire class**. Student learning is enhanced when students are provided the opportunity to discuss clicker responses with peers combined with instructor explanation of answers (Smith *et al.*, 2011).
Flipped courses	**Videos are preferred over extensive reading from the textbook**. Use established evidence-based practices to create short, engaging videos that are closed captioned (Brame, 2016). **Provide interactive note-taking guides**. Participants described that “fill-in-the-blank” notes from the instructor supported their learning. This helped them take notes during the lecture portions of some STEM courses and could also support textbook reading and video watching for flipped courses. Organize video links and provide students with suggestions for how to use the videos to prepare for class. Be explicit about the length of the videos and invite students to take notes while watching.
Course materials	Select textbooks with built-in voice-to-text features that students can readily access. Provide detailed reading assignment schedules to students, ideally by the first day of the course. This helps students, because they can share these schedules with the DRC to create accessible forms of readings in a timely manner. If you use primary literature or other reading sources not found in a textbook, then have PDF versions of these readings readily available. If you are contacted by the accessible media team at your DRC, you can provide the PDFs in a timely manner, which supports student access.
Course structure	Apply extended-time accommodations to reading quizzes, pop quizzes, and graded clicker questions. Offer students options to take pop quizzes before class starts or after class so they can use extended-time accommodations without missing class instruction.
Environment	Invite students who feel highly distracted in a SCALE-UP–type classroom to meet with you to find the least distractable seat in the room. You could share this invitation verbally at the start of the class or by posting it in your course syllabus or on the course website.

[a]Bold text indicates suggestions offered by participants. We do not consider these suggestions to represent a panacea ensuring full accessibility of a course. These suggestions are founded on the specific barriers, and some of the supports identified by participants in our study.

students with ADHD/SLD, and other disabilities, within STEM majors.

ACKNOWLEDGMENTS

We thank our participants and members of the University of Georgia's (UGA) DRC speakers' bureau. We acknowledge Evie Reiter and McKenna Hendrickson for their contribution to preliminary analysis for this project. We are grateful to our present and past DRC partners: Erin Benson, Sam Adair, and Pat Marshall. We also thank our Biology Education Research Group colleagues, especially Tessa Andrews, Peggy Brickman, and Paula Lemons, for their ongoing support and feedback through the lifetime of this project. We especially want to acknowledge Stephanie Halmo, Trevor Tuma, Emily Bremers, and Emmierose Scates for their helpful feedback on early iterations of this work. This material is based upon work supported by the NSF Graduate Research Fellowship Program under grant no. 1842396 (in support of M.A.P.). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF. This research was also supported in part by funds from the Division of Student Affairs at UGA (to J.D.S. and M.A.P.).

REFERENCES

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

Andrews, T. M., Leonard, M. J., Colgrove, C. A., & Kalinowski, S. T. (2011). Active learning not associated with student learning in a random sample of college biology courses. *CBE—Life Sciences Education*, *10*(4), 394–405. https://doi.org/10.1187/cbe.11-07-0061

Batty, L., & Reilly, K. (2022). Understanding barriers to participation within undergraduate STEM laboratories: Towards development of an inclusive curriculum. *Journal of Biological Education*. https://doi.org/10.1080/00219266.2021.2012227.

Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J. J., Allain, R. J., Bonham, S. W., … & Risley, J. S. (2007). The Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) project. 43. In Redish, E. F., and Cooney, P. J. (eds.), *PER-based reform in university physics* (Vol. 1, pp. 2–39). College Park, MD: American Association of Physics Teachers.

Bergmann, J., & Sams, A. (2012). Flip your classroom: Reach every student in every class every day. Eugene, OR: International Society for Technology in Education.

Bogart, K. R., & Dunn, D. S. (2019). Ableism special issue introduction. *Journal of Social Issues*, *75*(3), 650–664.

Boysen, G. A. (2021). Lessons (not) learned: The troubling similarities between learning styles and universal design for learning. *Scholarship of Teaching and Learning in Psychology*. Advance online publication. https://doi.org/10.1037/stl0000280

Brame, C. J. (2016). Effective educational videos: Principles and guidelines for maximizing student learning from video content. *CBE—Life Sciences Education*, *15*(4), es6. https://doi.org/10.1187/cbe.16-03-0125

Brigati, J. R., England, B. J., & Schussler, E. E. (2020). How do undergraduates cope with anxiety resulting from active learning practices in introductory biology? *PLoS ONE*, *15*(8), e0236558. https://doi.org/10.1371/journal.pone.0236558

CAST. (2018). *Universal design for learning guidelines version 2.2*. Retrieved October 15, 2021, from http://udlguidelines.cast.org

Cooke, J. E., Weir, L., & Clarkston, B. (2019). Retention following two-stage collaborative exams depends on timing and student performance. *CBE—Life Sciences Education*, *18*(2), ar12.

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. https://doi.org/10.1187/cbe.16-01-0074

Cooper, K. M., Downing, V. R., & Brownell, S. E. (2018). The influence of active learning practices on student anxiety in large-enrollment college science classrooms. *International Journal of STEM Education*, *5*(1), 23. https://doi.org/10.1186/s40594-018-0123-6

Cox, T. D., Ogle, B., & Campbell, L. O. (2019). Investigating challenges and preferred instructional strategies in STEM. *Journal of Postsecondary Education and Disability*, *32*(1), 49–61.

Daly-Cano, M., Vaccaro, A., & Newman, B. (2015). College student narratives about learning and using self-advocacy skills. *Journal of Postsecondary Education and Disability*, *28*(2), 213–227.

Dancy, M., Henderson, C., & Turpen, C. (2016). How faculty learn about and implement research-based instructional strategies: The case of peer instruction. *Physical Review Physics Education Research*, *12*(1), 010110. https://doi.org/10.1103/PhysRevPhysEducRes.12.010110

Dewsbury, B., & Brame, C. J. (2019). Inclusive teaching. *CBE—Life Sciences Education*, *18*(2), fe2. https://doi.org/10.1187/cbe.19-01-0021

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. https://doi.org/10.1187/cbe.19-09-0186

Driessen, E. P., Knight, J. K., Smith, M. K., & Ballen, C. J. (2020). Demystifying the meaning of active learning in postsecondary biology education. *CBE—Life Sciences Education*, *19*(4), ar52. https://doi.org/10.1187/cbe.20-04-0068

Druckman, J. N., Levy, J., & Sands, N. (2021). Bias in education disability accommodations. *Economics of Education Review*, *85*, 102176.

Dunn, C., Rabren, K. S., Taylor, S. L., & Dotson, C. K. (2012). Assisting students with high-incidence disabilities to pursue careers in science, technology, engineering, and mathematics. *Intervention in School and Clinic*, *48*(1), 47–54.

DuPaul, G. J., Gormley, M. J., & Laracy, S. D. (2013). Comorbidity of LD and ADHD: Implications of DSM-5 for assessment and treatment. *Journal of Learning Disabilities*, *46*(1), 43–51. https://doi.org/10.1177/0022219412464351

Eddy, S. L., Converse, M., & Wenderoth, M. P. (2015). PORTAAL: A classroom observation tool assessing evidence-based teaching practices for active learning in large science, technology, engineering, and mathematics classes. *CBE—Life Sciences Education*, *14*(2), ar23. https://doi.org/10.1187/cbe.14-06-0095

Eddy, S. L., & Hogan, K. A. (2014). Getting under the hood: How and for whom does increasing course structure work? *CBE—Life Sciences Education*, *13*(3), 453–468. https://doi.org/10.1187/cbe.14-03-0050

England, B. J., Brigati, J. R., & Schussler, E. E. (2017). Student anxiety in introductory biology classrooms: Perceptions about active learning and persistence in the major. *PLoS ONE*, *12*(8), e0182506. https://doi.org/10.1371/journal.pone.0182506

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences USA*, *111*(23), 8410. https://doi.org/10.1073/pnas.1319030111

Friedensen, R., Lauterbach, A., Kimball, E., & Mwangi, C. G. (2021). Students with high-incidence disabilities in STEM: Barriers encountered in postsecondary learning environments. *Journal of Postsecondary Education and Disability*, *34*(1), 77–90.

Gin, L. E., Guerrero, F. A., Cooper, K. M., & Brownell, S. E. (2020). Is active learning accessible? Exploring the process of providing accommodations to students with disabilities. *CBE—Life Sciences Education*, *19*(4), es12. https://doi.org/10.1187/cbe.20-03-0049

Gonzalez, F. G. (2017). The impacts of active learning on learning disabled students. *Paper presented at 2017 ASEE Annual Conference & Exposition held on June 24, 2017 at Columbus, Ohio*.

Haak, D. C., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. *Science*, *332*(6034), 1213. https://doi.org/10.1126/science.1204820

Hadley, W. M. (2006). L.D. Students' access to higher education: Self-advocacy and support. *Journal of Developmental Education*, *30*(2), 10–16.

Hedrick, B., Dizen, M., Collins, K., Evans, J., & Grayson, T. (2010). Perceptions of college students with and without disabilities and effects of STEM and non-STEM enrollment on student engagement and institutional involvement. *Journal of Postsecondary Education and Disability*, *23*(2), 129–136.

Hong, B. S. (2015). Qualitative analysis of the barriers college students with disabilities experience in higher education. *Journal of College Student Development*, *56*(3), 209–226.

Hood, S., Barrickman, N., Djerdjian, N., Farr, M., Magner, S., Roychowdhury, H., … & Hull, K. (2021). "I like and prefer to work alone": Social anxiety, academic self-efficacy, and students' perceptions of active learning. *CBE—Life Sciences Education*, *20*(1), ar12. https://doi.org/10.1187/cbe.19-12-0271

Hupfeld, K. E., Abagis, T. R., & Shah, P. (2019). Living "in the zone": Hyperfocus in adult ADHD. *ADHD Attention Deficit and Hyperactivity Disorders*, *11*(2), 191–208. https://doi.org/10.1007/s12402-018-0272-y

Izzo, M., & Lamb, M. (2002). *Self-determination and career development: Skills for successful transitions to postsecondary education and employment (Post-School Outcomes Network of the National Center on Secondary Education and Transition [NCSET] at the University of Hawaii at Manoa white paper)*. Retrieved November 24, 2021, from www.supporteddecisionmaking.org/legal-resource/self-determination-and-career-development-skills-successful-transitions-postsecondary

James, W., Bustamante, C., Lamons, K., Scanlon, E., & Chini, J. J. (2020). Disabling barriers experienced by students with disabilities in postsecondary introductory physics. *Physical Review Physics Education Research*, *16*(2), 020111. https://doi.org/10.1103/PhysRevPhysEducRes.16.020111

Janiga, S. J., & Costenbader, V. (2002). The transition from high school to postsecondary education for students with learning disabilities: A survey of college service coordinators. *Journal of Learning Disabilities*, *35*(5), 463–470.

Jensen, J. L., Holt, E. A., Sowards, J. B., Heath Ogden, T., & West, R. E. (2018). Investigating strategies for pre-class content learning in a flipped classroom. *Journal of Science Education and Technology*, *27*(6), 523–535. https://doi.org/10.1007/s10956-018-9740-6

Jimenez, T. C., Graf, V. L., & Rose, E. (2007). Gaining access to general education: The promise of universal design for learning. *Issues in Teacher Education*, *16*(2), 41–54.

Lasky, A. K., Weisner, T. S., Jensen, P. S., Hinshaw, S. P., Hechtman, L., Arnold, L. E., … & Swanson, J. M. (2016). ADHD in context: Young adults' reports of the impact of occupational environment on the manifestation of ADHD. *Social Science & Medicine*, *161*, 160–168. https://doi.org/10.1016/j.socscimed.2016.06.003

Lee, A. (2022). A forgotten underrepresented group: Students with disabilities' entrance into STEM fields. *International Journal of Disability, Development and Education*, *69*(4), 1295–1312. https://doi.org/10.1080/1034912X.2020.1767762

Leight, H., Saunders, C., Calkins, R., & Withers, M. (2012). Collaborative testing improves performance but not content retention in a large-enrollment introductory biology class. *CBE—Life Sciences Education*, *11*(4), 392–401.

Lombardi, D., & Shipley, T. F. (2021). The curious construct of active learning. *Psychological Science in the Public Interest*, *22*(1), 8–43. https://doi.org/10.1177/1529100620973974

Love, T. S., Kreiser, N., Camargo, E., Grubbs, M. E., Kim, E. J., Burge, P. L., & Culver, S. M. (2015). STEM faculty experiences with students with disabilities at a Land Grant institution. *Journal of Education and Training Studies*, *3*(1), 27–38.

Martin, J. E., & Marshall, L. H. (1995). ChoiceMaker: A comprehensive self-determination transition program. *Intervention in School and Clinic*, *30*(3), 147–156. https://doi.org/10.1177/105345129503000304

Miller, R. A., & Downey, M. (2020). Examining the STEM climate for queer students with disabilities. *Journal of Postsecondary Education and Disability*, *33*(2), 169–181.

Moon, N. W., Todd, R. L., Morton, D. L., & Ivey, E. (2012). *Accommodating students with disabilities in science, technology, engineering, and mathematics (STEM)* (pp. 8–21). Atlanta: Center for Assistive Technology and Environmental Access, Georgia Institute of Technology

National Science Foundation. (2021). *Women, minorities, and persons with disabilities in science and engineering (NSF 21-321)*. Retrieved September 23, 2022, from https://ncses.nsf.gov/wmpd

Newman, L., Wagner, M., Knokey, A.-M., Marder, C., Nagle, K., Shaver, D., & Wei, X. (2011). *The post-high school outcomes of young adults with disabilities up to 8 years after high school: A report from the national longitudinal transition study-2 (NLTS2)* (NCSER 2011-3005). Washington, DC: National Center for Special Education Research.

Nieminen, J. H., & Pesonen, H. V. (2020). Taking universal design back to its roots: Perspectives on accessibility and identity in undergraduate mathematics. *Education Sciences*, *10*(1), 12.

Nieminen, J. H., & Pesonen, H. V. (2022). Politicising inclusive learning environments: How to foster belonging and challenge ableism? *Higher Education Research & Development*, *41*(6), 2020–2033.

Offerdahl, E. G., McConnell, M., & Boyer, J. (2018). Can I have your recipe? Using a fidelity of implementation (FOI) framework to identify the key ingredients of formative assessment for learning. *CBE—Life Sciences Education*, *17*(4), es16. https://doi.org/10.1187/cbe.18-02-0029

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education*, *25*, 85–95. https://doi.org/10.1016/j.iheduc.2015.02.002

Peña, E. V. (2014). Marginalization of published scholarship on students with disabilities in higher education journals. *Journal of College Student Development*, *55*(1), 30–40.

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. https://doi.org/10.1187/cbe.20-06-0107

Pfeifer, M. A., Reiter, E. M., Hendrickson, M., & Stanton, J. D. (2020). Speaking up: A model of self-advocacy for STEM undergraduates with ADHD and/or specific learning disabilities. *International Journal of STEM Education*, *7*(1), 33. https://doi.org/10.1186/s40594-020-00233-4

Pulukuri, S., & Abrams, B. (2021). Improving learning outcomes and metacognitive monitoring: Replacing traditional textbook readings with question-embedded videos. *Journal of Chemical Education*, *98*(7), 2156–2166. https://doi.org/10.1021/acs.jchemed.1c00237

Raue, K., & Lewis, L. (2011). *Students with disabilities at degree-granting postsecondary institutions. First Look* (NCES 2011-018). Washington, DC: National Center for Education Statistics.

Reaser, A., Prevatt, F., Petscher, Y., & Proctor, B. (2007). The learning and study strategies of college students with ADHD. *Psychology in the Schools*, *44*(6), 627–638. https://doi.org/10.1002/pits.20252

Reinholz, D. L., & Ridgway, S. W. (2021). Access needs: Centering students and disrupting ableist norms in STEM. *CBE—Life Sciences Education*, *20*(3), es8.

Saldaña, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). Los Angeles, CA: Sage.

Satparam, J., & Apps, T. (2022). A systematic review of the flipped classroom research in K–12: Implementation, challenges and effectiveness. *Journal of Education, Management and Development Studies*, *2*(1), 35–51. https://doi.org/10.52631/jemds.v2i1.71

Scanlon, E., Legron-Rodriguez, T., Schreffler, J., Ibadlit, E., Vasquez, E., & Chini, J. J. (2018a). Postsecondary chemistry curricula and universal design for learning: Planning for variations in learners' abilities, needs, and interests. *Chemistry Education Research and Practice*, *19*(4), 1216–1239.

Scanlon, E., Schreffler, J., James, W., Vasquez, E., & Chini, J. J. (2018b). Postsecondary physics curricula and universal design for learning: Planning for diverse learners. *Physical Review Physics Education Research*, *14*(2), 020101.

Schneps, M. H., Brockmole, J. R., Sonnert, G., & Pomplun, M. (2012). History of reading struggles linked to enhanced learning in low spatial frequency scenes. *PLoS ONE*, *7*(4), e35724. https://doi.org/10.1371/journal.pone.0035724

Schreffler, J., Vasquez, E., III, Chini, J., & James, W. (2019). Universal design for learning in postsecondary stem education for students with disabilities: A systematic literature review. *International Journal of STEM Education*, *6*(1). 8. https://doi.org/10.1186/s40594-019-0161-8

Seipp, B. (1991). Anxiety and academic performance: A meta-analysis of findings. *Anxiety Research*, *4*(1), 27–41. https://doi.org/10.1080/08917779108248762

Shifrer, D., & Mackin Freeman, D. (2021). Problematizing perceptions of STEM potential: Differences by cognitive disability status in high school and postsecondary educational outcomes. *Socius*, *7*, 2378023121998116.

Sins Invalid. (2019). *Skin, tooth, and bone: The basis of movement is our people* (2nd ed.). Berkeley, CA.

Smith, M. K., Jones, F. H. M., Gilbert, S. L., & Wieman, C. E. (2013). The Classroom Observation Protocol for Undergraduate STEM (COPUS): A new instrument to characterize university stem classroom practices. *CBE—Life Sciences Education*, *12*(4), 618–627. https://doi.org/10.1187/cbe.13-08-0154

Smith, M. K., Wood, W. B., Krauter, K., & Knight, J. K. (2011). Combining peer discussion with instructor explanation increases student learning from in-class concept questions. *CBE—Life Sciences Education*, *10*(1), 55–63. https://doi.org/10.1187/cbe.10-08-0101

Stains, M., & Vickrey, T. (2017). Fidelity of implementation: An overlooked yet critical construct to establish effectiveness of evidence-based instructional practices. *CBE—Life Sciences Education*, *16*(1), rm1. https://doi.org/10.1187/cbe.16-03-0113

Stanton, J. D., Dye, K. M., & Johnson, M. (2019). Knowledge of learning makes a difference: A comparison of metacognition in introductory and senior-level biology students. *CBE—Life Sciences Education*, *18*(2), ar24. https://doi.org/10.1187/cbe.18-12-0239

Tanner, K. D. (2013). Structure matters: Twenty-one teaching strategies to promote student engagement and cultivate classroom equity. *CBE—Life Sciences Education*, *12*(3), 322–331. https://doi.org/10.1187/cbe.13-06-0115

Test, D. W., Fowler, C. H., Wood, W. M., Brewer, D. M., & Eddy, S. (2005). A conceptual framework of self-advocacy for students with disabilities. *Remedial and Special Education*, *26*(1), 43–54.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., ... & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences USA*, *117*(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117

Thompson-Ebanks, V., & Jarman, M. (2018). Undergraduate students with nonapparent disabilities identify factors that contribute to disclosure decisions. *International Journal of Disability, Development and Education*, *65*(3), 286–303. https://doi.org/10.1080/1034912X.2017.1380174

Thurston, L. P., Shuman, C., Middendorf, B. J., & Johnson, C. (2017). Postsecondary STEM education for students with disabilities: Lessons learned from a decade of NSF funding. *Journal of Postsecondary Education and Disability*, *30*(1), 49–60.

Waugh, A. H., & Andrews, T. C. (2020). Diving into the details: Constructing a framework of random call components. *CBE—Life Sciences Education*, *19*(2), ar14. https://doi.org/10.1187/cbe.19-07-0130

Wilson, K., Brickman, P., & Brame, C. (2018). Evidence based teaching guide: Group work. *CBE—Life Sciences Education*, *17*(1), fe1. https://doi.org/10.1187/cbe.17-12-0258