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A Multi-Year Longitudinal Study Exploring the Impact of the COVID-19 Pandemic on Students' Familiarity and Perceptions of Active Learning

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A multi-year longitudinal study exploring the impact of the COVID-19 pandemic on students' familiarity and perceptions of active learning

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Abstract

The COVID-19 pandemic caused nearly ubiquitous emergency remote teaching in both secondary and post-secondary education. While there has been a plethora of work examining how instructors adjusted classes to incorporate active learning during emergency remote teaching, there has only been minimal work examining how such emergency remote teaching may have influenced students' perceptions of active learning. Here, we conduct a longitudinal multi-cohort study at one institution across nine semesters before, during, and after emergency remote teaching due to the pandemic to explore how college students' familiarity and perceptions of active learning have shifted over time because of the pandemic. Our results reveal decreases in familiarity with active learning during emergency remote teaching, with familiarity remaining lower than pre-COVID even after the end of emergency remote teaching. In addition, our results indicate shifts in students' perceptions of active learning, leading to potentially higher student resistance to active learning following emergency remote teaching. We conclude by discussing implications for instructors to better support active learning and promote engagement in active learning classes following the end of emergency remote teaching.

Keywords: active learning, emergency remote teaching, student familiarity with active learning

Introduction

A large body of literature across science, technology, engineering, and math (STEM) disciplines has demonstrated that active learning (a broad category of instructional activities that usually involve students being actively engaged in their own learning during a class as opposed to more traditional lecture-based classes) can increase student learning, decrease differences in performance across different demographics of students, and promote student persistence and retention (Armbruster, Patel, Johnson, & Weiss, 2009; Chi & Wylie, 2014; Freeman et al., 2014; Haak, HilleRisLambers, Pitre, & Freeman, 2011; Kvam, 2000; Theobald et al., 2020). Despite these benefits, many instructors and faculty perceive multiple barriers for implementing active learning techniques in their STEM courses, and the frequency of instructors using active learning remains low (Hora & Ferrare, 2013; Michael, 2007; Miller & Metz, 2014; Stains et al., 2018). These barriers include the fear of student resistance to active learning, with many faculty reporting concerns that students will not engage in active learning or will not see the utility of such practices in the classroom, leading to potentially lower attendance, enrollment, or student evaluations of teaching (Henderson, Khan, & Dancy, 2018; Michael, 2007; Nguyen et al., 2021; Owens, Sadler, Barlow, & Smith-Walters, 2020).

Given these concerns, there have been multiple prior attempts at characterizing student perceptions of active learning and identifying potential sources of resistance to active learning (Patrick, 2020). This work has led to at times contrasting results. For instance, a survey of students in physiology courses identified that nearly all students (91%) indicated that they “have become accustomed to lecture-based methods”, with nearly half agreeing that active learning is not a “productive use of class time” (Miller & Metz, 2014), with other work also identifying that students perceive lecture-based instruction as more effective than active learning (Tsang & Harris, 2016). Similarly, many students in an introductory biology course stated that they preferred having more lecture instead of active learning, and cited naïve conceptions regarding the purpose and benefits of active learning (Owens et al., 2020). However, despite these views, other studies across disciplines have found at times contradictory results. For instance, Lumpkin, Achen, & Dodd (2015) identified that students largely saw value in active learning after participating in active learning activities, a finding echoed by Machemer & Crawford (2007), and Gonsar, Patrick, & Cotner (2021) found that most students in STEM courses across three universities wanted more active learning in their STEM courses. Other work has revealed that students reported increased perceptions of learning after participating in active learning as compared to traditional lecture-based instruction (Kressler & Kressler, 2020; Smith & Cardaciotto, 2011) and that faculty may often overestimate the level of student resistance to active learning (M. E. Andrews et al., 2020).

These at-times contrasting results may be due to differences in how active learning is implemented in the classroom, as well as variation in student backgrounds and identities that influence their perceptions of active learning. For instance, there remains widespread variation in how instructors conceptualize active learning, which can lead to a diversity of approaches all classified under this term (T. C. Andrews, Auerbach, & Grant, 2019; T. M. Andrews, Leonard, Colgrove, & Kalinowski, 2011; M. M. Cooper, 2016; Driessen, Knight, Smith, & Ballen, 2020; Prince, 2004). Likewise, different students with different identities may experience active learning differently. For example, students with different levels of social anxiety and self-efficacy may perceive and experience active learning differently (England, Brigati, Schussler, & Chen, 2019; Hood et al., 2021), and students with ‘hidden identities’ (i.e., any descriptors of a student’s identity that cannot be seen from a student’s outward appearances) may also have more negative experiences with active learning (Henning, Ballen, Molina, & Cotner, 2019).

This body of literature examining student perceptions of active learning, however, is limited in several ways. First, nearly all the existing work has examined student perceptions of active learning *after* a specific module or course that implemented active learning, measuring student experiences in those environments. Students’ perceptions of active learning in those studies are thus likely heavily influenced by specific course, instructor, and group attributes in the class. In contrast, very few studies have investigated student perceptions of and familiarity with active learning *prior* to participating in an active learning course. Examining student familiarity and perceptions of active learning prior to courses that rely heavily on active learning is important since such factors can influence how much a student chooses to engage with active learning and impact potential resistance to active learning (K. M. Cooper, Ashley, & Brownell, 2017). We describe how these perceptions may impact student engagement with active learning more in our theoretical framework section below. Second, most studies have relied on examining student perceptions of active learning at one timepoint, with very little work done examining how student perceptions of active learning have changed over time in different cohorts of students. This lack of longitudinal work is particularly striking in the context of the COVID-19 pandemic, which led to sudden and nearly universal emergency remote teaching (ERT) across institutions in the United States and worldwide in spring 2020 and widespread reports of lower student engagement (Nichols, Xia, Parco, & Bailey, 2022; Shim & Lee, 2020; Walsh, Arango-Caro, Wester, & Callis-Duehl, 2021; Wester, Walsh, Arango-Caro, & Callis-Duehl, 2021). Some classes adopted synchronous ERT, while other instructors utilized asynchronous ERT, leading to potentially different experiences across classes (Fabriz, Mendzheritskaya, & Stehle, 2021; Reyes-Rojas & Sánchez, 2022). Similarly, ERT led to changes in how many instructors implemented office hours and assessments in their courses(Hsu, Rowland-Goldsmith, & Schwartz, 2022; Panadero, Fraile, Pinedo, Rodríguez-Hernández, & Díez, 2022). While there is work exploring how instructors adapted their active learning during the pandemic (e.g., Baldock, Fernandez, Franco, Provencher, & McCoy, 2021; Morrison, Naro-Maciel, & Bonney, 2021; Singhal, 2020) as well as potential changes in student learning and student affect (Bawa, 2020; Carrasco-Hernández, Lozano-Reina, Lucas-Pérez, Madrid-Garre, & Sánchez-Marín, 2023; Iglesias-Pradas, Hernández-García, Chaparro-Peláez, & Prieto, 2021; Panadero et al., 2022; Wilhelm, Mattingly, & Gonzalez, 2022), we are not aware of any work that has directly examined how the pandemic and emergency remote teaching has influenced student perceptions of active learning. We also note that the majority of work examining active learning (and indeed, the majority of work in STEM education research) has focused upon large, research-intensive universities, with relatively few studies examining student perceptions of active learning in the context of smaller, comprehensive institutions that are primarily undergraduate within STEM (Lo et al., 2019).

In addition, we also highlight how there is a lack of work examining if students' STEM identity – or the extent a student sees themselves as a member of the STEM community or as a scientist (Le, Doughty, Thompson, & Hartley, 2019; Trujillo & Tanner, 2014) – can influence their perception of active learning, or if students' perceptions of active learning can impact their STEM identity. Past work has suggested that active learning can impact STEM identity, with most studies indicating positive impact (Ballen, Wieman, Salehi, Searle, & Zamudio, 2017; Dou, Brewe, Potvin, Zwolak, & Hazari, 2018; Major & Kirn, 2017; Olivera, 2022). Other studies have also found that engaging in authentic scientific practices, a key component of many types of active learning in STEM, is also positively correlated with STEM identity (Singer, Montgomery, & Schmoll, 2020). Similarly, another study situated in the context of undergraduate introductory biology courses identified that students with higher STEM identity perceive classroom climate more positively in an active learning class than those with lower STEM identity, suggesting that STEM identity can influence students' perceptions of instructional practices (Starr et al., 2020). In sum, this body of literature suggests that there are possible correlations between STEM identity and how a student perceives active learning, though this correlation remains unclear given the lack of empirically grounded studies examining this relationship.

Here, we draw upon a longitudinal, multi-cohort set of surveys deployed to students prior to taking an introductory molecular genetics course across nine semesters that span from before to after the onset of the COVID-19 pandemic. These data allow us to investigate several research questions:

1. How familiar with active learning are students in an introductory biology course focusing on molecular genetics at the start of the course?
2. How do these students perceive active learning?
3. What is the impact of the COVID pandemic on students' familiarity and perceptions of active learning? Are there any longitudinal trends in students' familiarity and perceptions?

4. Are there correlations between students' STEM identity and their perceptions of active learning?

Theoretical framework

We situate our study using the lens of expectancy value theory (EVT). EVT is a commonly applied framework in the learning sciences that states that students who value a given task and also expect to do well on the task are more likely to cognitively engage with the given task (J. Eccles, 1983; J. S. Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). This framework has previously been applied to explore students' engagement with and perceptions of active learning across contexts. For instance, Cavanagh et al. (2016) apply EVT as a framework to define student "buy-in" of active learning, exploring how students' exposure and familiarity to active learning shape their expectations and motivation to engage with active learning. Similarly, Wiggins et al. (2017) rely on focus groups and surveys to identify that students' perceived value of active learning activities influences their personal effort in these activities, utilizing EVT as a framework to explore how these expectations, along with instructional practices, impact student perceptions. EVT has also been used as a framework to explore the efficacy of specific active learning activities and classroom interventions, including in the context of activities in undergraduate microbiology (Rholl et al., 2023), animal science (Ragland, Radcliffe, & Karcher, 2023), and introductory biology (Nugent, 2019). Other work, while not explicitly drawing upon EVT, investigate student expectations of active learning, finding that what students expect to happen in a classroom and what they expect to happen with active learning shape their engagement in the classroom (Lemelin et al., 2021; Nguyen et al., 2021). Past work has also identified that potential differences in expectations between students and instructors regarding active learning can also influence both student and instructor behavior in the classroom (M. E. Andrews et al., 2020).

Taken together, this work suggests that investigating students' familiarity with and expectations of active learning can provide insight into students' level of engagement with active learning. Indeed, a systematic literature review of studies around student resistance and negative responses to active learning identifies EVT as a relevant theory and highlights how students' value beliefs, i.e., their perceived utility and sense of value of the active learning activities, as well as their level of familiarity of active learning, play major roles in determining students' level of engagement (Shekhar et al., 2020). Here, we draw upon EVT and use a model developed for exploring the level that students choose to engage (or not engage) during active learning activities to situate our work (K. M. Cooper et al., 2017). Under this model, three main components shape students' achievement-related choices in active learning: their expectation of success (i.e., learning) when doing active learning; the perceived value of engaging during the active learning activity; and the perceived cost of engaging in the active learning activity (K. M. Cooper et al., 2017). Cooper et al. (2017) thus posit that students' level of familiarity with active learning prior to the active learning, as well as their perceptions of what active learning is, will influence their expectations and perceived value of participating in the active learning activity and their level of potential resistance to active learning. Given this framework, our work involves surveying students prior to the start of an introductory course to characterize students' level of familiarity with active learning as well as their definitions and perceptions of active learning, which will all influence students' expectations and perceived values and thus their engagement in active learning activities.

Methods

Institution and course context

This study took place at a private, comprehensive university in southern California with an R2 designation under the Carnegie Classifications. The university is a primarily undergraduate institution within most of the STEM disciplines and within biology and the life sciences. For instance, there are no graduate programs in any of the natural sciences. Undergraduate courses thus do not have any teaching assistants, and range in size from around 50-80 students in each section at the introductory level. This study took place in the context of an introduction to molecular genetics course that was previously described (Hsu & Rowland-Goldsmith, 2021). This course, which is offered in both fall and spring semesters, typically serves as either the second or third course in the introductory biology sequence, depending on major. For example, students majoring in health sciences and applied human physiology, as well as those in the university's pre-pharmacy program, usually take this course in their second semester of college, after taking an introductory biology course focusing on cell and molecular biology. In contrast, biology majors usually take this course as their third semester of biology (after taking a course focusing on ecology and evolution in their second semester).

Survey design

The instructors of the introduction to molecular genetics course (including JLH) designed a pre-class survey to get to know their students, address concerns, and adjust the course accordingly. This pre-class survey encompassed three Likert-scale questions that are used for our study here:

- I am familiar with active learning. This question was scored on a scale of "I am not at all familiar with active learning" (a numerical response of 1) to "I am very familiar with active learning" (a numerical response of 5).
- I learn best when my professors lecture the entire class period. This question was scored on a "strongly disagree" to "strongly agree" scale.
- I am a scientist. This question was scored on a "strongly disagree" to "strongly agree" scale.

The first two questions were designed *de novo* to capture both students' familiarity with active learning, as well as their perceived sense of learning with lecture-only classes that do not utilize active learning. The third statement was derived from a published 5-item science identity scale that has previously been used in biology classes to measure STEM identity (Estrada, Woodcock, Hernandez, & Schultz, 2011; McCartney et al., 2022). We only included one statement here, given that these surveys were designed for class purposes (and not for research purposes), and length of the survey was a concern.

Finally, an open-ended question was asked to capture students' perceptions of active learning: "If you have heard of active learning before, what words first come to mind when someone mentions active learning? In other words, what words/terms do you associate with active learning?"

Survey deployment

This pre-class survey was deployed each semester between spring 2018 and spring 2022, encompassing nine semesters. The survey was distributed to students using the course learning management software a week before the start of term and closed on the first day of class. Completion was incentivized with bonus points, and several reminders were sent to students about the importance of completing this pre-class survey, particularly when the course was online during the COVID-19 pandemic (given that the survey included questions asking about technological access and needs). Given this, response rates were extremely high, with over 80% of students completing the survey each semester (table I). Overall, 1,146 students responded to the survey, representing a nearly 93% completion rate across the semesters.

This study was reviewed and approved by the Chapman University Institutional Review Board.

Table I. Enrollment of students and survey completion rates. *This completion rate for fall 2020 is over 100% since enrollment data was gathered after the drop deadline the second week of the semester, so one student likely completed the pre-class survey but then did not stay enrolled in the course. No data is available for the number of students that dropped the course during the first two weeks of the semester during these terms, but the instructors report typically never having more than 2-3 students dropping the class during this period.

Semester	Number of students enrolled	Number of survey respondents (percent of total)
Spring 2018	159	144 (90.6%)
Fall 2018	98	95 (96.9%)

Spring 2019	190	177 (93.2%)
Fall 2019	99	95 (96.0%)
Spring 2020	172	157 (91.3%)
Fall 2020	94	95* (101.1%*)
Spring 2021	163	162 (99.4%)
Fall 2021	99	83 (83.8%)
Spring 2022	162	138 (85.1%)
Total	**1,236**	**1,146 (92.7%)**

Course demographics

We compiled aggregate demographic data for gender, major, and class year across these semesters. The majority of students (72.3%) identified as female, with 27.6% identifying as male (the rest identified as non-binary or declined to state their gender). Most students were first-years (55.3%), with over a quarter of respondents as second year students (27.1%). Far fewer were third years (11.8%) or fourth years (4.2%), with the remaining 1.7% consisting of students in their fifth year or above, post-baccalaureate students, or students who declined to provide their class year. Finally, we identify that most students are life science majors: 42.1% are health sciences majors, followed by 18.7% biology majors, 16.2% pre-pharmacy students, 11.2% biochemistry majors, and 7% applied human physiology majors (formerly known as the kinesiology major). No other major had over 2% representation in our population. Demographics remained largely constant each year, with the course taken predominantly by first- and second-year life sciences students as a major requirement.

Coding of open-ended responses and analyses

Both researchers independently read through 25 random responses to the open-ended question and generated a codebook. Next, the two researchers discussed to create a consensus codebook, applying this codebook to the initial 25 responses. After this, the two researchers independently coded 30 responses and then calculated Cohen's kappa using ReCal 2.0 (Freelon, 2013). Kappa was 0.67, indicating "substantial" agreement between the coders (Landis & Koch, 1977b, 1977a). Given this high interrater reliability, one coder coded the remaining responses.

Responses to both the open-ended and Likert-scale questions were then compared longitudinally. We divided our responses into three main periods. First, we compiled spring 2018 through spring 2020 (five semesters) as terms that were pre-COVID. The COVID pandemic started in spring 2020, with most institutions (including ours) moving to emergency remote instruction in March 2020. We thus grouped the spring 2020 semester with the pre-COVID group since the beginning of term survey would have been completed prior to the pandemic andERT. Next, we grouped fall 2020 and spring 2021 together as terms with ERT during the COVID pandemic. Finally, we grouped the last two semesters (fall 2021 and spring 2022) together as terms that occurred after the pandemic began that did not rely on ERT and instead had a return to in-person learning. We compared student familiarity, level of agreement with learning best through lecture, and STEM identity across these periods using t-tests. In addition, we also compared students' perceptions of active learning across the time periods by comparing the frequency of codes in each period. Finally, given that first-year students may have different experiences than their peers who are in their second year and above, we compared students' familiarity with active learning, their level of agreement with learning best through lecture, and STEM identity between first-year students and students who are in their second year or above,

Results

How familiar with active learning are students in an introductory biology course focusing on molecular genetics at the start of the course?

Most students (51.2%) responded with a 4 or 5 to the statement “I am familiar with active learning”, indicating that they were either familiar or very familiar with active learning (table II). Approximately a fifth of students (18.9%) reported not being familiar with active learning or only minimally familiar. Approximately a third of students responded with a “3”, indicating that they were somewhat familiar with active learning. First-year students reported being less familiar with active learning than students in their second year and above (supplemental table I; two sample t-test, $p<0.01$).

Table II. Student familiarity with active learning

Familiarity	Percent of respondents
Responded with a 1 (Not at all familiar with active learning)	7.1%
Responded with a 2	11.9%
Responded with a 3	29.8%
Responded with a 4	35.0%
Responded with a 5: Very familiar with active learning	16.1%

How do these students perceive active learning?

Analysis of the open-ended responses led to seven emergent themes that were found across more than 1% of student responses (table III). The majority of students associated active learning with greater participation in class, including perceiving that there was greater engagement in active learning classes. Nearly a fourth of students associated active learning with critical thinking or higher order cognitive skills, with approximately a fifth identifying active learning with small group activities and collaboration with partners, and another 20% with small group or whole class discussions. Interestingly, 10% of respondents stated that active learning involved asking more questions during class. Nearly 10% of students indicated that they correlated active learning with either active study strategies (e.g., “active reading”) or assessment (e.g., “assessing yourself”). Finally, approximately 6% of respondents indicated that they associated active learning with being more alert or attentive in class. These themes were largely similar between first-year students and students in their second year and above (supplemental table 2).

Table III. Student perceptions of active learning, when asked what words they associated with active learning

Code Name	Code description	Example quotes	Percent of respondents
Participation	Discussed engaging in class or participating during class, including engaging with the instructor and other students	“student involvement”, “participation”	58.3%
Critical thinking	Associated active learning with higher order cognitive skills, including problem solving and applying concepts	“When you apply what you learn in order to really grasp the concept and remember it vs. just memorizing it for a short period of time.”	24.3%
Collaboration	Specifically associated active learning with small group activities	“Group work or hands on”	20.5%

Discussion	Stated that active learning consists of dialogue within small groups or with the entire class	"talking with peers", "discussion", "communication"	19.8%
Asking questions	Ascribed active learning to the asking of questions in class	"asking questions"	10.7%
Study strategies	Stated that active learning is associating with active studying or assessment	"active reading, assessing yourself"	7.0%
Attention	Cited paying more attention or being more alert in class	"Alert, proactive, passionate" "focusing"	6.3%

What is the impact of the COVID pandemic on students' familiarity and perceptions of active learning? Are there any longitudinal trends in students' familiarity and perceptions?

The COVID-19 pandemic impacted students' familiarity of active learning, with the level of familiarity dropping once ERT started (Figure 1; *M* = 3.63 and 2.80 for pre-COVID and during emergency remote teaching, respectively; $p < 0.001$, two-sample t-test). This change represented an effect size of 0.84, considered a large level of change (Cohen, 2016). Students' level of familiarity with active learning increased after the conclusion of ERT (*M* = 3.28 after ERT; $p < 0.001$, two-sample t-test; effect size of 0.38), though remained below that of pre-COVID levels ($p < 0.001$, two-sample t-test). These trends were observed for both first-year students and students in their second year and above (supplemental table 3).

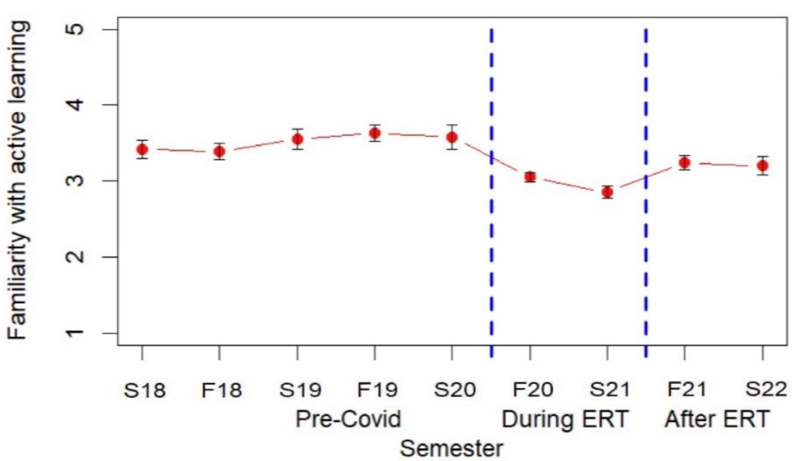

Figure 1. Students' self-reported level of familiarity with active learning.

Interestingly, there were similar changes in students' self-reported perceptions of learning when their instructor lectures the entire period. Before COVID, the mean Likert-scale value was 2.81 (figure 2), indicating that students, on average, were slightly disagreeing with the statement that they learn best when the instructor lectures the entire period. The plurality of students indicated that they were neutral to this statement (a Likert-scale value of 3). However, during ERT, students' perceptions changed, with students now indicating a slight agreement to this statement (*M* = 3.21; figure 2), showing an increase in students' agreement that they learn best with lecture-based courses (p-value < 0.001; two-sample t-test; effect size of 0.39). There was no change in students' perception between ERT and after the conclusion of ERT (*M* = 3.06; $p > 0.05$; two-sample t-test; effect size of 0.15). These trends were consistent for both first-year students as well as students in their second year or above (supplemental table 4).

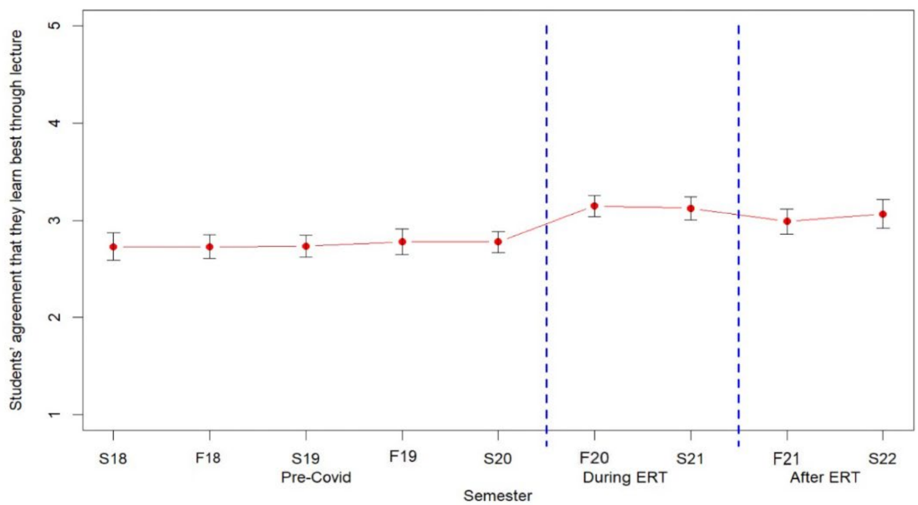

Figure 2. Students' level of agreement with the statement "I learn best when my professors lecture the entire class period."

Our data also showed changes in students' perceptions of active learning during ERT, with a decreased percentage of students indicating that they associated active learning with participation, collaboration, discussion, and attention, and increases in percentage of students indicating that they associated active learning with critical thinking, asking questions, and study strategies (table IV; all comparisons $p < 0.001$; Chi-square test with post-hoc Bonferroni correction), suggesting shifts in students' perceptions of active learning. The percent of respondents that associated active learning with each of these seven themes increased after the end of ERT ($p < 0.001$; Chi-square test with post-hoc Bonferroni correction), with the exception of the participation and attention codes.

Table IV. Perceptions of active learning by time period

	Percent of respondents		
Code name	**Pre-COVID**	**During ERT**	**After ERT**
Participation	61.0%	55.6%	53.8%
Critical thinking	21.9%	25.8%	30.0%
Collaboration	24.6%	10.4%	18.3%
Discussion	22.8%	13.2%	17.2%
Asking questions	8.6%	13.2%	14.4%
Study strategies	3.3%	8.8%	16.1%
Attention	7.5%	4.4%	4.4%

Are there correlations between students' STEM identity and their perceptions of active learning?

There were no changes in students' STEM identity between any of the time periods (table V; two-sample t-test; $p > 0.05$), with most students agreeing or strongly agreeing that they are a scientist. Fewer than 12% of students indicated that they disagreed or strongly disagreed with being a scientist in any of the periods. There were also no differences between how those students who had high STEM identity (i.e., those who agreed or strongly agreed that they were a scientist) and those who had low STEM identity (i.e., those who disagreed or strongly disagreed that they were a scientist) perceived active learning when we compared each of the seven codes (Chi-square test with post-hoc Bonferroni correction; $p > 0.05$). However, we identified that first-year students' STEM identity decreased from pre-COVID to during ERT, and remained at this lower level after ERT, while there was no significant change in the STEM identity for students in their second year or above across any of the time periods (supplemental table 5).

Table V. Students' average scores for STEM identity by time

	Pre-COVID	**During ERT**	**After ERT**
Mean value for STEM identity	3.61	3.51	3.47

Discussion

The COVID-19 pandemic caused a decrease in students' familiarity with active learning

Our work is the first we are aware of that examines student perceptions of active learning prior to engaging in an active learning course, as well as the first study we are aware of that investigates how the COVID-19 pandemic has impacted student perceptions of active learning. First, we find that students' familiarity with active learning dropped during ERT and continues to be lower than pre-COVID, even in the semesters after the end of ERT, and that this pattern held both for first-year students (who would not have any collegiate experiences with in-person active learning classes during ERT) as well as students in their second year and above. While our survey did not explore the reasons for students' familiarity (or lack thereof) with active learning, this decrease in student familiarity with active learning may stem from a number of factors. First, many instructors struggled with the transition to ERT (Moorhouse & Kohnke, 2021; Walsh et al., 2021), and surveys of instructors consistently demonstrated that the number of scientific teaching practices – including active learning in the virtual classroom – decreased after the transition to ERT (Durham, Colclasure, & Brooks, 2022). Similarly, many courses in both high schools and colleges transitioned to asynchronous classes (Guo, 2020; Meltzer et al., 2021), a format that poses unique challenges for instructors, many of whom are not trained in asynchronous teaching, to implement active learning(Heffernan, Murphy, & Yearwood, 2022; Venton & Pompano, 2021). We speculate that these changes in instruction and the likely decrease in exposure to active learning during ERT led to students' decreased familiarity with active learning. Second, there was a concomitant decrease in student engagement and an increase in student stress and anxiety as the pandemic started, given the large health and economic pressures that many students faced (Hsu & Goldsmith, 2021; Spitzer, Gutsfeld, Wirzberger, & Moeller, 2021; Wester et al., 2021). Even if some instructors were able to implement the same frequency of active learning during ERT as before the pandemic, it is possible that this decrease in student emotional engagement and participation in class may impact students' experiences and perceptions, contributing to the observed lower familiarity with active learning.

This decrease in familiarity with active learning was accompanied by an increase in students perceiving that they learn best when their instructors lecture the entire period, meaning no active learning is taking place. We contextualize this increase in perception that lecturing supports learning and decreased familiarity with active learning by drawing upon the framework for examining student perceptions of active learning based on EVT (K. M. Cooper et al., 2017). Under this model, students' familiarity with active learning prior to a course influences both their expectations of what will occur in an active learning classroom and their perceived value of participating in active learning. This model is supported by past work identifying that low familiarity with active learning can potentially lead to decreased motivation in active learning classrooms and lower "buy in" to such activities (Cavanagh et al., 2016; Shekhar et al., 2020). Thus, these changes may potentially lead to students being more resistant to active learning since the start of the COVID pandemic unless there is instruction that explains and familiarizes students with active learning. Our data suggest that more students may have a lowered perceived value of participating in active learning activities given the increased number of students indicating that they learn best with a class consisting solely of lecturing, indicating that students may come into an active learning class with lower motivation to engage in active learning because of their unfamiliarity with these techniques. In addition, students may have more incorrect expectations of what participating in an active learning class means if they are less familiar with active learning than previous cohorts of students, again potentially contributing to greater resistance to active learning.

Students report diverse conceptions of active learning

Under the framework of active learning engagement based on EVT, students' perceived value of participating in active learning activities is also heavily influenced by how they perceive active learning (K. M. Cooper et al., 2017). In addition, past work has indicated that differences in how students and instructors value active learning and how they perceive such activity can shape student and instructor behaviors (M. E. Andrews et al., 2020). Our results indicate that there is no consensus on how undergraduate students entering the molecular genetics course perceive active learning. Instead, students provided fairly diverse responses that ranged from associating active learning with more participation and engagement in class, to linking active learning with higher order thinking and paying more attention in class (table III). While we did not ask students to define active learning, these responses provide insight into how students are perceiving active learning and their conceptions of what it means to participate in active learning. Intriguingly, this lack of consensus among students is consistent with past work that has demonstrated a similar diversity of conceptions of active learning among biology faculty and biology education research (BER) papers focusing on active learning (Driessen et al., 2020). For instance, the most common response provided by biology instructors defined active learning as “students interacting or engaging with the material,” which was also the most commonly cited definition in the BER literature (Driessen et al., 2020). The second most commonly cited definition for active learning in both the instructor survey and BER literature defined active learning as the opposite of lecturing (i.e., characterizing active learning as “not lecturing”), followed by defining active learning as consisting of group work (Driessen et al., 2020).

Parts of our students' conceptions of active learning appear to align with these three definitions of active learning. For instance, the majority of students stated that they viewed active learning as engaging and participating more in class, in line with instructors' conceptions as well as the most common definition used in the BER literature. Similarly, the third and fourth most common responses that our respondents provided (that they associated active learning with collaboration and discussion) matched the second and third most common active learning strategies mentioned by instructors (Driessen et al., 2020). However, despite this alignment, there were a few areas where students were conceptualizing active learning in different ways than by either instructors or the BER literature. For instance, the second most common response students provided in our study was that they associated active learning with critical thinking, likely perceiving classes with active learning as incorporating more questions that require higher order cognitive skills. While past studies have indicated that active learning can promote the development of students' critical thinking skills (Kim, Sharma, Land, & Furlong, 2013; Styers, Van Zandt, & Hayden, 2018), it is interesting that neither instructors nor the BER literature define active learning as being characterized by critical thinking or higher order cognitive skills, showing a potential disconnect in how students and instructors are thinking about and defining active learning. Similarly, while our respondents mentioned group work and discussion, we note that none of our students explicitly mentioned metacognition or assessment, two of the most frequently cited active learning strategies by instructors and the BER literature (Driessen et al., 2020).

There are several possible reasons for these disconnects between how students and instructors are viewing active learning, and we draw upon variation theory to provide a framework for discussing these differences (J. Bussey, Orgill, & J. Crippen, 2013). Variation theory posits that instructors have an intended object of learning, i.e., their goals when choosing and implementing class activities, but that the enacted and lived objects of learning (i.e., what happens and what students perceive and take away from the lesson, respectively) may vary due to students attending to different features during the class and having different perspectives and backgrounds (J. Bussey et al., 2013). Thus, it is possible that these students may have had prior experiences with active learning focused on metacognition, but that the students may not have recognized the reflective nature of the activities nor realized that they were being prompted to think about their own thinking. Similarly, students may have experienced previous active learning classes with formative assessments, but rather than recognizing the role of such assessments to provide feedback on their learning, may have focused more on the higher-level cognitive nature of such questions, leading to the differences in how instructors and students are describing active learning.

In addition, past work has found that instructors' past exposure to active learning plays a major role in shaping how they conceptualize and implement active learning, with large variation in how instructors incorporate active learning in classes (T. C. Andrews et al., 2019; Van Amburgh, Devlin, Kirwin, & Qualters, 2007). Similarly, past work utilizing EVT has identified that instructors' familiarity with active learning also influences their motivations for implementing active learning or for pursuing professional development relating to active learning (McCourt et al., 2017; McPartlan, Thoman, Poe, A Herrera, & Smith, 2022). It is therefore likely that students' past exposure to different active learning techniques (and thus their level of familiarity with active learning) also shapes their conceptions of active learning (Daouk, Bahous, & Bacha, 2016; Lumpkin et al., 2015; Machemer & Crawford, 2007). Thus, it is possible that differences in students' previous backgrounds and familiarity with active learning (and how their past instructors approached active learning) may influence their conceptions of active learning, leading to the variation we observed in our results and the disconnects between some of these conceptions and those of instructors.

Intriguingly, approximately 10% of students in our work highlighted how they associated active learning with being able to ask questions. These associations suggest that students may be more comfortable asking questions to peers and instructors in active learning classes, which may be a result of students participating in small group activities or whole class discussions in active learning classes as compared to lecture-based classes. It is also interesting to note that some students associated active learning with implementing more active study strategies or paying more attention in class, highlighting how these students are likely perceiving additional benefits of active learning that extend beyond the classroom and likely shaping their expectations of what active learning entails.

Changes in perceptions of active learning and in STEM identity

We find shifts in students' perceptions of active learning after the start of ERT, with fewer students associating active learning with participation, collaboration, discussion, and paying attention, consistent with our hypotheses that students are engaging in fewer active learning activities that involve collaborating or discussing questions with their peers during ERT. . Despite this, the relative frequencies of the codes largely remained the same between pre-COVID, ERT, and after ERT, suggesting that despite a drop in familiarity with active learning during and after ERT, students are still primarily conceptualizing active learning in similar ways as before the COVID pandemic. We also did not see any differences in how students with high or low STEM identities viewed active learning. While past work has identified that active learning can shape students' STEM identity and increase sense of belonging (Liu, Yang, & Ho, 2022; Major & Kirn, 2017; Moudgalya, Mayfield, Yadav, Hu, & Kussmaul, 2021), we are not aware of any previous work that has explicitly examined if students with different levels of STEM identity have different perceptions of active learning prior to engaging in an active learning course. However, past work has found that the level of a student's STEM identity can impact how they perceive a classroom, suggesting that students with different levels of STEM identities may perceive active learning different and engage differently as well (Starr et al., 2020). More work is needed in the future to fully investigate if there are more nuanced differences in how these students think about active learning that our survey was unable to capture. Similarly, we identified that there was a decrease in first-year students' STEM identity during ERT, a decrease not seen in students in their second year and above. Further work is needed to explore this change in more depth, though we speculate that this difference may be attributed to first-year students' lack of experience with in-person college experiences during ERT, as compared to students in their second year and above who previously had in-person experiences with college classes and the college community.

Limitations

We acknowledge several limitations of our work. First, our work is limited to one institution, and it is possible that specific institutional characteristics may influence students' conceptions of active learning. For instance, it is plausible that older students may be sharing their views on active learning with incoming students, thus biasing their views, or that instructors in previous courses may also be discussing or defining active learning with the students. Second, we recognize that our work is constrained by the nature of our instrument, which was designed for pedagogical purposes to allow the instructors of the course to better adjust their classes. As such, the survey only asked students what words they associated with active learning and did not ask them to define this term, and also relied on a limited number of Likert-scale questions. More work in the future that incorporates validated instruments, including surveys designed using EVT as a framework, and interviews with students across a diversity of institutions will provide a more comprehensive understanding of how students across the United States are conceptualizing active learning and the impacts of the COVID-19 pandemic on perceptions of active learning. Finally, we note that our work provided a longitudinal examination of how different cohorts of students before, during, and after ERT conceptualize active learning, but did not provide any longitudinal tracking of a given cohort of students to see how their specific perceptions of active learning changed over time. Future work that tracks incoming students (who likely experienced ERT in their high school classes) and investigates how their conceptions of active learning change over time will provide important insights into how ERT shifted students' perceptions of active learning and what factors influence these perceptions over time.

Despite these limitations, our study provides the first work we are aware of that explores how the COVID pandemic influenced students' conceptions of active learning and provides insight into how ERT impacted students' familiarity with and expectations of active learning. In addition, our work provides a unique examination of student conceptions of active learning at the start of an active learning course, allowing for greater understanding of how students in an introductory-level biology course perceive active learning before engaging with such techniques in the class. Finally, we highlight how our work adds to the existing literature base on active learning by examining student conceptions of active learning at an institution that is primarily undergraduate in the life sciences, in contrast to the majority of BER literature that is based on studies conducting at large, research-intensive universities (Lo et al., 2019).

Implications for instructors

Our work provides several implications for instructors:

- **Explicitly define and justify the use of active learning at the start of courses.** Our work demonstrates that the COVID-19 pandemic and ERT led to a decrease in students' familiarity with active learning and a concomitant increase in percentage of students who think that they learn best in a lecture-only class, despite overwhelming evidence that active learning is beneficial for student learning and retention (Armbruster et al., 2009; Freeman et al., 2014; Freeman, Haak, & Wenderoth, 2011; Haak et al., 2011; Theobald et al., 2020). Under the model based on EVT, these decreases in familiarity (and the increases in expectation that students learn best when the instructor lectures the entire period) will likely lead to greater resistance to active learning. Thus, instructors who intend to use active learning can take steps at the beginning of the course (and throughout the term) to guide students' expectations and values regarding active learning by explaining pedagogical choices (Seidel, Reggi, Schinske, Burrus, & Tanner, 2015). This includes incorporating discussion on what types of activities that students will encounter in the class, as well as a conversation about the reasoning for using such active learning techniques (i.e., justifying the choice of active learning by highlighting the benefits for student learning). Instructors can also implement related strategies centered around explaining and facilitating active learning that can mitigate resistance for active learning (Tharayil et al., 2018) as well as interventions that promote student engagement for specific types of activities such as groupwork and message boards (Clinton & Kelly, 2020b, 2020a).

- **Explore different types of active learning strategies and be cognizant of potential differences in how students and instructors perceive active learning.** Our work reveals that students are conceptualizing active learning in many ways, similar to how there is no consensus among instructors about what active learning is. Given the wide variation in how active learning is perceived, instructors may wish to explore and integrate a multitude of active learning approaches in their classes and rely on the existing literature that guides instructors on implementation of such approaches. For instance, we highlight a recent literature review that provides an overview of instructor strategies to aid implementation of active learning (Nguyen et al., 2021) as well as past essays designed to guide instructors in thinking about a range of active learning strategies (e.g., Allen & Tanner, 2005). Instructors should also be aware of potential disconnects in how students and instructors are conceptualizing active learning; for instance, our study revealed that none of our surveyed students associated active learning with metacognition or assessment, in contrast to many biology education instructors and the BER literature defining active learning as such (Driessen et al., 2020). Instructors can thus take steps to address this disconnect by highlighting and discussing the benefits of any metacognitive active learning activities they do in class, including activities that incorporate formative assessment, and guide students towards more metacognition both inside and outside the class. We direct instructors to a recent evidence-based teaching guide on metacognition that may be of interest (Stanton, Sebesta, & Dunlosky, 2021).

- **Discuss how active learning can help promote critical thinking and higher-order cognitive skills and scaffold the class to develop such skills.** Our results suggest that many students are associating active learning with critical thinking and higher-order cognitive skills, in contrast to biology instructors and the BER literature, which do not define active learning in a similar way (Driessen et al., 2020). These student perceptions are consistent with past work that has found that students in active learning classes are using more cognitive effort than students in lecture-based courses (Deslauriers, McCarty, Miller, Callaghan, & Kestin, 2019). However, this study found that students expending more cognitive effort in active learning classes led to the students believing that they were learning less in such active learning classes (despite evidence that they were actually learning more than in the lecture-based class) (Deslauriers et al., 2019). Taken together, these data suggest that instructors should be aware of the potential disconnect between how they and the students are viewing active learning and can take steps to influence students' expectations of active learning accordingly. For instance, instructors can discuss how active learning requires more cognitive effort but will lead to greater learning gains. Similarly, instructors can scaffold their classes accordingly to support and develop such critical thinking skills.

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Data availability statement

The full set of student responses are not shared publicly to protect participants' privacy and per IRB regulations. However, we have shared all instruments, coding techniques, and results in this manuscript and the supplement.

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