

Biology Students' Perspectives & Recommendations on Exam-Related Anxiety in Undergraduate Biology Courses

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ABSTRACT

Exam anxiety has been well-documented to reduce student performance in undergraduate biology courses, especially for students from marginalized groups, which can contribute to achievement gaps. Our exploratory study surveyed 61 undergraduate biology students to better understand how exams affect their anxiety levels, focusing on the impact of exam types, proctoring practices, and time constraints. We also solicited students' preferences for exam type and recommendations for improving the structure of exams in undergraduate biology courses. Our findings indicate that closed-note exams and proctoring practices, such as LockDown Browser, significantly heightened student anxiety. Conversely, open-note and cheat-sheet exams were associated with lower anxiety levels as these formats allowed students to focus on understanding concepts rather than rote memorization. Students also provided recommendations for improving exam structure, such as allowing students to use some form of notes, reducing time constraints, and balancing exam difficulty with exam length. These findings contribute to the growing body of literature on test anxiety in undergraduate biology courses and provide practical insights for biology instructors seeking to create more supportive and equitable assessment practices.

Key Words: cheat sheet; traditional exam; closed-note exam; high-stakes exam; open-note exam; online exam; proctoring; crib sheet.

○ Introduction

Exams are a common summative assessment tool used to evaluate student performance in college courses, yet test anxiety can lead to poor performance on exams and ultimately lower GPA (Cassady & Johnson, 2002; Chapell et al., 2005). Test anxiety is the range of cognitive, physiological, and behavioral responses that hinder a student's ability to perform well on assessments (Zeidner, 1998). Gerwing et al. (2015) found that nearly 40% of surveyed undergraduate students reported experiencing test anxiety. This percentage may be even higher in Science, Technology, Engineering, and Mathematics (STEM) courses, which are often perceived as particularly rigorous and where traditional exams typically make up a large portion of the course grade. Indeed, numerous studies across STEM disciplines consistently demonstrate that test anxiety can

significantly impair academic performance (Ali & Mohsin, 2013; DordiNejad et al., 2011; England et al., 2019; Harris et al., 2019; Shapiro, 2014).

In college biology courses specifically, test anxiety has been correlated with lower exam scores that can result in academic achievement gaps for students from systemically excluded groups in STEM (e.g., women, students of color) (Ballen et al., 2017; Cotner & Ballen, 2017; Cotner et al., 2020; England et al., 2019; Farrar et al., 2023; Salehi et al., 2019; Salehi et al., 2021). For example, despite similar academic preparation as their peers, test anxiety disproportionately harms the exam performance of women (Ballen et al., 2017). A similar pattern has been shown across nine introductory biology courses where women underperformed on high-stakes exams when compared with men (Cotner & Ballen, 2017). It is worth noting that university context and students' academic preparation can play a significant role in determining the extent to which test anxiety influences achievement gaps on exams across demographic groups (Salehi et al., 2019; Salehi et al., 2020; Salehi et al., 2021). For instance, Salehi et al. (2021) found that underrepresented minority students in introductory STEM courses at some four-year universities had higher test anxiety, which was associated with lower exam scores; however, this pattern was not observed at community colleges. Regardless of the context or university setting, it is concerning that test anxiety manifests such disparate impacts on different student groups within college biology courses. For students from systemically excluded groups in biology, these patterns may be explained in part by stereotype threat—the fear of confirming negative societal stereotypes during high-stakes assessments (e.g., certain individuals do not belong in STEM) (Steele, 1997; Steele & Aronson, 1995). Considering the correlation between test anxiety and achievement gaps on exams in biology courses and evidence that higher anxiety levels prompt students to leave the biology major (England et al., 2017; England et al., 2019), the use of traditional closed-note exams in college biology courses needs to be re-evaluated.

Adopting a course deficit model, which identifies structural barriers in a course that contribute to performance gaps rather than placing responsibility solely on students (Cotner & Ballen, 2017), provides a useful lens for re-evaluating the efficacy of traditional, high-stakes exams in college biology courses. From this

perspective, biology instructors can explore alternative exam formats to reduce exam anxiety (Hsu & Goldsmith, 2021), such as allowing cheat sheets where students prepare notes on paper or an index card to use during the exam or open-note exams that permit reference to full notes or textbook. The availability of cheat sheets or open notes during exams can decrease student anxiety and stress (Durning et al., 2016; Erbe, 2007; Gharib et al., 2012; Smith & Lester, 2019) and consequently increase exam performance (Block, 2012; Gharib et al., 2012; Settlege & Wollscheid, 2019) (but see Dickson & Miller, 2005; Sato et al., 2015). This improvement in performance may be due to a shift in focus from rote memorization to a deeper understanding of concepts (Driessen et al., 2022). For instance, open-note exams in an undergraduate biology course were perceived by students as supporting a deeper understanding of the material as they invested considerable effort in creating effective notes (Driessen et al., 2022). Thus, adjusting exam formats can play a significant role in reducing anxiety and promoting deeper learning.

In addition to the use of cheat sheets or open-note exams, the shift to online learning during the COVID-19 pandemic exposed many students to online exams for the first time, which may have influenced both their preferences for this exam format and their anxiety levels. Online exams have been found to lower anxiety in college students (Cassady & Gridley, 2005; Stowell & Bennett, 2010) and result in similar exam scores as in-person exams in college chemistry courses (Hilaire & Franco, 2023). During the pandemic, the introduction of online exams in college science courses offered more flexibility, which students perceived as beneficial because it allowed them a larger window of time to complete the exam compared with traditional in-class settings (Wilhelm et al., 2022). Ewell et al. (2022) found that students' exam-related anxiety was lower at the start of the pandemic, but this reduction in anxiety diminished after the first month as students encountered additional stressors. A major contributor to exam-related anxiety during the pandemic was the use of remote proctoring tools (e.g., Proctor U, Proctorio, and Respondus LockDown Browser), which are intended to ensure academic integrity but are rooted in a student deficit mindset that assumes students will cheat. Remote proctoring tools can heighten students' feelings of surveillance and stress (Balash et al., 2021; Mohammed et al., 2021; Pennino et al., 2022; Terpstra et al., 2023; Woldeab & Brothen, 2019), especially for women and Latiné students (Mohammed et al., 2021). In a survey of 200 undergraduate STEM students, more than half reported experiencing moderate to very high levels of anxiety when using LockDown Browser for exams and quizzes in online courses during the pandemic (Pennino et al., 2022). Understanding the impact of different exam formats and proctoring practices on student anxiety is crucial for developing more supportive assessment strategies in undergraduate biology courses.

While prior research has examined the effects of exam anxiety and alternative exam formats on student performance, much of this work has been conducted at research-intensive institutions with less attention given to students at primarily undergraduate institutions (PUIs) – such as the one in the present study. There is also limited research on undergraduate biology students' preferences for different exam types and proctoring methods, as well as how these factors affect their perceived anxiety levels. Our exploratory study addresses this gap by investigating biology students' perspectives on various exam formats at a PUI with a diverse student body. By centering student voices, our study provides new insights into how biology students perceive different assessment strategies and offers

recommendations for designing exams that better support students in undergraduate biology courses. We addressed the following research questions:

1. To what extent do undergraduate biology students perceive that their anxiety levels are influenced by
 - a. exam types?
 - b. exam proctoring practices?
 - c. exam time constraints?
2. What types of exams do undergraduate biology students perceive best support their learning of biology concepts and why?
3. What recommendations do undergraduate biology students offer to improve the structure of exams in undergraduate biology courses?

By investigating these questions, our exploratory study aims to provide practical insights that biology instructors can use to redesign exams in ways that reduce students' exam-related anxiety.

○ Methods

Participant Recruitment

This study was conducted at a medium-sized, master's granting institution on the west coast that is designated as a Hispanic-Serving Institution and primarily undergraduate institution with 85% of students being local to the region and commuting to campus. At the time of the study, undergraduate students identified as 61% female, 57% Persons Excluded due to Ethnicity or Race (PEERs; students who identify as Black or African American, Hispanic or Latinx, or Native American) (Asai, 2020), 73% students of color (i.e., African American, Asian, Hispanic or Latinx, Native American, Pacific Islander, or any of these designations), 58% first-generation college students, and 40% transfer students.

To assess the perceptions and experiences of undergraduate biology students about exam-related anxiety, we invited 505 undergraduate students majoring in biology or biotechnology who were enrolled full-time to participate in this exploratory study. The study was administered through a Qualtrics survey during June–July 2022. Study participants were recruited in the summer to ensure they had experiences across a multitude of biology courses to draw on for this study. Participation was incentivized by inviting students to enter an optional raffle. This study was approved by the Institutional Review Board at California State University San Marcos (#1903253-1).

Data Collection: Survey Development & Validity

The survey consisted of Likert-scale and open-ended questions that assessed how various exam types, exam proctoring practices, and exam time constraints influenced biology students' perceived anxiety levels. Students were asked to report their perceived anxiety levels (high, moderate, low, or no anxiety) across in-person and online exams with varying degrees of note availability (closed note, some notes or cheat sheet, or open note). During survey validation, students suggested adding "cheat sheet" alongside the "some notes" option for clarity; hereafter, we use cheat sheet throughout the manuscript. Students also rated their anxiety levels for different proctoring practices, such as in-person proctoring, LockDown Browser with video on and video off, online exam with video camera on, and online exam with no proctoring. Additional open-ended questions

asked students to describe how time constraints influenced their exam-related anxiety, their preferences for exam type, and to provide recommendations for improving exam structure in undergraduate biology courses. Students were invited to self-identify their demographics at the end of the survey; demographic questions for students' gender and sexual identity were adapted from Casper et al. (2022). See the Supplemental Materials provided with the online version of this article for the survey questions used in data analysis.

Survey questions were validated by disseminating the survey to 10 undergraduate students majoring in biology, biochemistry, or kinesiology as these majors enroll in multiple biology courses to complete their degree. Two researchers (S.N.S. and A.M.V.) had in-person meetings with each student to solicit feedback to improve the clarity of survey questions. Based on the students' feedback, minor adjustments were made to the survey to improve the clarity of the survey questions.

Statistical Data Analyses

We calculated the proportion of students who shared how in-person or online exams with closed notes, cheat sheet, or open notes influenced their anxiety levels. Students had the option of selecting "Not Applicable" as a response to this survey question, and we assumed this indicated no prior experience with that exam type based on validation feedback where students stated this was their interpretation. Less than 2% of students ($n = 1-2$) selected "Not Applicable" for in-person or online exams. Separate ordinal logistic regressions were used to assess how student anxiety levels (high, moderate, low, or no anxiety) varied with exam type (closed note, cheat sheet, or open note) for in-person and online exams. For each model, "high anxiety" was set as the reference category for the dependent variable, and "closed note" was the reference category for the independent variable.

We investigated students' perceptions of how proctoring practices during exams in undergraduate biology courses influenced their anxiety levels by calculating the proportion of students who shared how different proctoring practices influenced their anxiety levels. For this survey question, students had the option of selecting "Not Applicable," and we assumed this indicated no prior experience with that proctoring practice based on validation feedback where students stated this was their interpretation. Less than 4% of students ($n = 1-2$) had not experienced one of the proctoring practices, thus we opted to include all the proctoring practices in our data analysis. Ordinal logistic regression was used to assess how student anxiety levels (high, moderate, low, or no anxiety) varied with exam proctoring practices. For the model, "high anxiety" was set as the reference category for the dependent variable, and "in person with the instructor in the classroom" was the reference category for the independent variable.

All statistical analyses were conducted in R (v4.1.0) (R Development Core Team, 2017), and figures were produced using the *ggplot2* and *ggthemes* packages (Arnold, 2017; Wickham & Wickham, 2009). All ordinal logistic regressions were modeled using the *polr()* function (Ripley et al., 2013), estimated probabilities and odds ratios were calculated with the *Effect()* function (Fox & Weisberg, 2018). To account for the small sample size, we interpret the logistic regression results as exploratory rather than confirmatory.

Qualitative Data Analyses

Researchers (S.N.S., A.M.V., and M.M.R.) collaborated on developing codes for the open-ended questions after de-identifying the qualitative data. Open-ended survey questions asked students

about how time constraints during exams influenced their anxiety levels, which exam types they perceived best support their learning of biology concepts, and their recommendations for improving the structure of exams in undergraduate biology courses. For each open-ended survey question, researchers first independently read each response and took detailed notes (Saldaña, 2021). Then, two rounds of inductive coding were used to assign each response a code (Saldaña, 2021). During the first round of coding, researchers collaborated on developing a codebook to assign each students' response a code. During the second round of coding, researchers coded each response independently using the codebook and discussed discrepancies until consensus was reached for each code.

Results

Participant Demographics

A total of 71 undergraduate students majoring in biology and biotechnology responded to the survey out of the 505 students who were invited (14% participation rate). Ten participants were removed from the data because most of their survey responses were left blank, leaving a total of 61 participants in the study. Demographics of study participants can be found in Table 1.

Student Anxiety Varies by Note Availability for In-Person & Online Exams

Overall, biology students' perceived anxiety levels varied based on note availability for in-person and online exams in undergraduate biology courses (Figure 1). For in-person exams, student anxiety levels differed significantly depending on note availability (ordinal logistic regression; $\chi^2 = 103.9$, $p < 0.0001$). Compared with in-person closed-note exams, the cumulative odds of reporting lower levels of anxiety (i.e., moderate, low, or no anxiety versus high anxiety) were 14.5 times higher for students using a cheat sheet and 67.9 times higher for those using open notes. This pattern reflects the substantially lower odds of reporting high anxiety for students using a cheat sheet (91% lower, $OR = 0.098$) or open notes (98% lower, $OR = 0.021$) for in-person exams (Table S1). Similar to in-person exams, anxiety levels for online exams also differed significantly depending on note availability (ordinal logistic regression; $\chi^2 = 81.8$, $p < 0.0001$). Compared to online closed note exams, the cumulative odds of reporting lower levels of anxiety (i.e., moderate, low, or no anxiety versus high anxiety) were 7.4 times higher for students using a cheat sheet and 34.6 times higher for those using open notes. This pattern is primarily explained by the lower odds of reporting high anxiety for students using a cheat sheet (86% lower, $OR = 0.049$) or open notes (97% lower, $OR = 0.010$) for online exams (Table S2).

Proctoring Practices Influence Student Anxiety Levels

Student anxiety levels varied depending on the exam proctoring practice used in undergraduate biology courses (ordinal logistic regression; $\chi^2 = 47.2$, $p < 0.0001$; Figure 2). Compared to in-person exams proctored by the instructor, the cumulative odds of reporting lower anxiety (i.e., moderate, low, or no anxiety versus high anxiety) were 73% lower for students taking an online exam with LockDown Browser and their video camera on ($OR = 0.27$). Relative to in-person exams with an instructor proctoring, the cumulative odds of reporting lower anxiety were 1.40 times higher for students taking an online exam with just LockDown Browser. Students

Table 1. Self-identified demographics of study participants ($n = 61$ study participants; $n = 49$ filled out the demographics form).

Demographic	Students % (n)	Demographic	Students % (n)
Women or Non-binary	76% (37)	Transfer student	31% (15)
Men	24% (12)	First-time freshman	69% (34)
PEER ¹	59% (29)	Low-socioeconomic background	47% (23)
Non-PEER	39% (19)	Not low-socioeconomic background	53% (26)
Decline to state	2% (1)		
		Disabled	8% (4)
Students of Color ²	80% (39)	Not disabled	92% (45)
White students	18% (9)		
Decline to state	2% (1)	Sophomore	18% (9)
		Junior	43% (21)
First-generation college student	45% (22)	Senior	39% (19)
Continuing-generation college student	55% (27)		

¹ PEER (Persons Excluded due to Ethnicity or Race) included any student who self-identified as African American or Black, Hispanic or Latinx, Native American or American Indian, or persons of mixed race who included any of these designations (Asai, 2020).

² Students of Color included any student who self-identified as African American or Black, Hispanic or Latinx, Native American or American Indian, Middle Eastern, East Asian, South Asian, Southeast Asian, Filipinx or Pacific Islander, or persons of mixed race who included any of these designations.

taking an online exam with their video camera on, with or without a microphone, had cumulative odds of reporting lower anxiety similar to in-person proctored exams ($OR = 0.93$). In contrast, the cumulative odds of reporting lower anxiety was 2.96 times higher for students taking an online or take-home exam with no proctoring. A more detailed breakdown of the odds ratios for each anxiety level across different proctoring practices is provided in Table S3.

Time Constraints Negatively Impact Student Anxiety

We analyzed responses to the open-ended question on how time constraints influenced students' perceived exam-related anxiety using emergent coding and calculated the percent of students whose responses were assigned each code ($n = 50$ students; see Table S4 for codebook). Student responses were coded into four emergent themes (Table 2). One-third of students ($n = 17/50$) shared that anxiety caused by time constraints negatively influenced their ability to share their biology knowledge during exams. For example, students shared that time constraints caused them to overthink answers, make mistakes, or caused anxiety regardless of how prepared they felt for the exam. For nearly 30% of students ($n = 15/50$), the influences of time constraints depended on the exam type, question type, and strategies they used to complete the exam. In their responses, students shared that multiple choice questions reduced anxiety while free response questions increased anxiety and that time constraints can influence their preference for exam type. Nearly 20% of students ($n = 11/50$) shared that time constraints caused anxiety if the time allotted was not sufficient to complete the exam. Yet nearly 16% of students ($n = 8/50$) shared time constraints had little to no effect on their anxiety levels during exams.

Biology Students Perceive That In-Person Exams with a Cheat Sheet Support Their Learning of Biology Concepts

Students were asked to identify which exam types they felt best supported their learning of biology concepts and could select from in-person and online exams with different levels of note availability, including closed-note, cheat-sheet, or open-note formats. Over half of students preferred in-person exams with a cheat sheet (57%, $n = 25/44$), while a third preferred in-person exams with open notes (34%, $n = 15/44$). A smaller percentage (18%, $n = 8/44$) preferred in-person exams with closed notes (Figure 3). In their

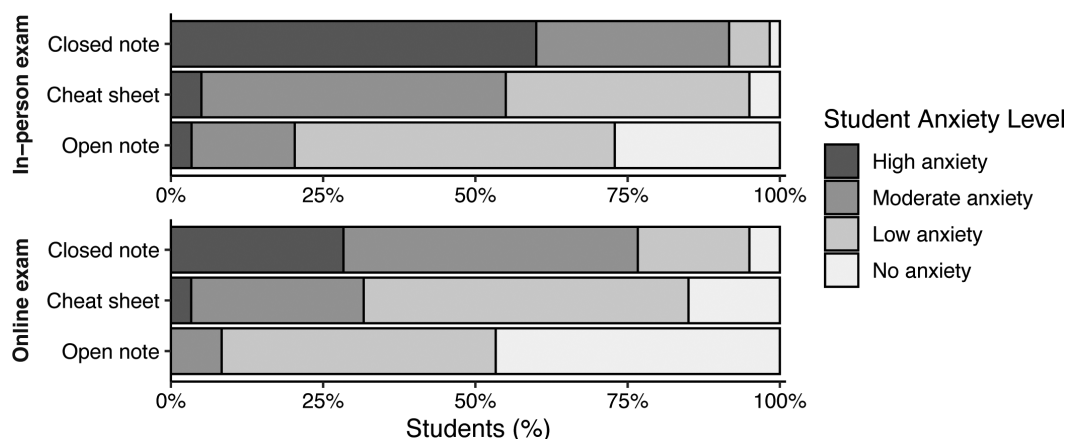


Figure 1. Percent of biology and biotechnology students who self-reported their perceived anxiety levels (high anxiety, moderate anxiety, low anxiety, or no anxiety) during in-person and online exams with varying degrees of note availability in their undergraduate biology courses ($n = 60$ students for in-person exams, $n = 61$ students for online exams).

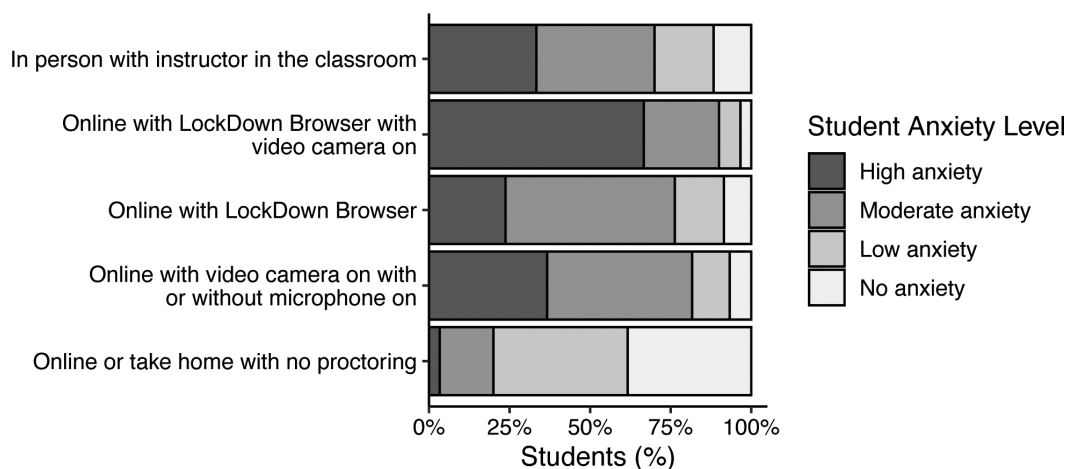


Figure 2. Percent of biology and biotechnology students who self-reported their perceived anxiety levels (high anxiety, moderate anxiety, low anxiety, or no anxiety) during various exam proctoring practices in their undergraduate biology courses ($n = 61$ students).

Table 2. Emergent codes in students' open-ended responses ($n = 50$ students) to the question "How do time constraints on exams influence your anxiety levels during test-taking in your undergraduate biology courses?"

Codes	Students % (n)
Anxiety caused by time constraints negatively influences students' ability to communicate their biology knowledge	33% (17)
Influence of time constraints depend on exam type, question type, and strategies used during the exam	29% (15)
Time constraints cause anxiety if the time allotted is not sufficient to complete the exam	22% (11)
Time constraints have little to no effect on student anxiety	16% (8)

open-ended responses, students shared that in-person exams with a cheat sheet reduced their exam-related anxiety and allowed them to focus more on learning the concepts rather than rote memorization, which supported their perceived long-term retention of course concepts. Over a third of students preferred online exams in an open-note format (36%, $n = 16/44$) while 21% ($n = 16/44$) favored online exams with a cheat sheet. A smaller percentage of students preferred online exams with closed notes (7%, $n = 3/44$). In their open-ended responses, students shared they preferred online open-note exams because they can take the exam at home, which reduces their anxiety about taking the exam in person. Examples of student rationales for preferring various exam types can be found in Table S5 (see Supplemental Material provided with the online version of this article).

Student Recommendations for Improving Exams in Undergraduate Biology Courses

To evaluate undergraduate biology students' recommendations for improving exams in biology courses, we used emergent coding to categorize their open-ended responses. As summarized in Table 3,

the recommendations include allowing open notes or cheat sheets, using varied exam formats, providing targeted study guides, offering diverse question types, reducing time constraints, and balancing question difficulty with exam length. The discussion section further explores these recommendations, offering suggestions for biology instructors on how to improve exam design in undergraduate biology courses.

Discussion

In this exploratory study, we examined undergraduate biology students' perceptions of exam-related anxiety and their recommendations for improving exam design in biology courses. Our findings suggest that anxiety levels may be significantly influenced by various exam conditions, including note availability, proctoring practices, and time constraints. Students in our sample reported higher anxiety during in-person and online exams when fewer notes were allowed, with the highest anxiety occurring during in-person, closed note exams. Similarly, online exams with LockDown Browser and video monitoring resulted in elevated anxiety compared with other proctoring methods. Time constraints also negatively impacted students' perceived ability to demonstrate their knowledge. In terms of learning, students in our study expressed a preference for in-person exams with a cheat sheet, which they perceived supported their understanding of course material by allowing them to focus on understanding concepts rather than memorization. Finally, students recommended varied exam formats, note allowances, and better alignment between exam length and difficulty to reduce anxiety and enhance their performance. Below, we discuss how diversifying exam formats, modifying proctoring practices, and altering time constraints can be implemented by biology instructors to potentially reduce students' exam-related anxiety in undergraduate biology courses.

Our findings, which indicate that students prefer in-person exams with cheat sheets or open notes, align with existing literature (Gharib et al., 2012; Smith & Lester, 2019) and contribute to an understanding of this preference within the context of biology courses. Students in this exploratory study reported that these exam formats reduced their anxiety and allowed them to focus on understanding the material rather than rote memorization. This sentiment has been echoed in previous research (Dickson & Bauer,

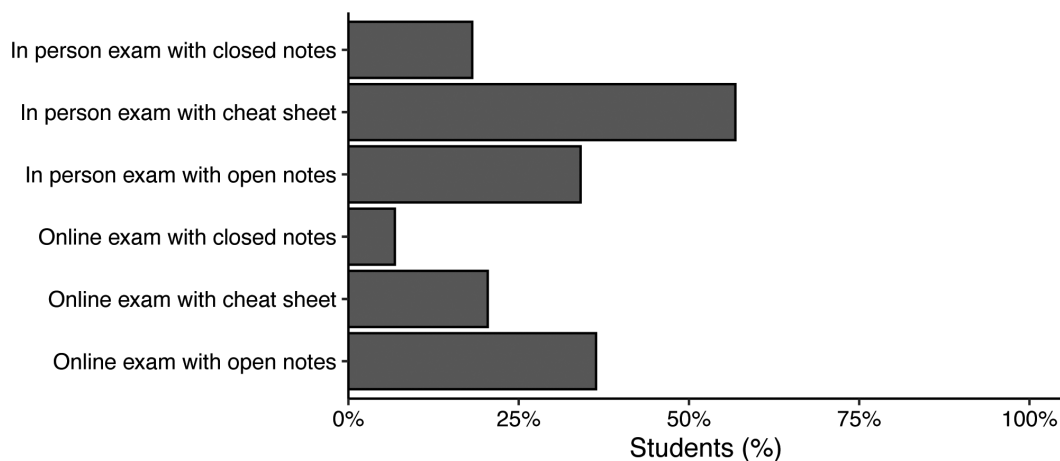


Figure 3. Percent of biology and biotechnology students who prefer in-person or online exams with varying degrees of note availability in their undergraduate biology courses ($n = 44$ students). Students were able to share multiple exam type preferences, so summed totals exceed 100%.

Table 3. Student recommendations for improving the structure of exams in undergraduate biology courses.

Recommendation 1:	Allow use of a “cheat sheet” during exams or make exams open note
Recommendation 2:	Use a variety of exam structures (e.g., group exams, take home, online exams)
Recommendation 3:	Provide study guides that reflect concepts on the exam
Recommendation 4:	Offer different types of exam questions so students can demonstrate their understanding of biology concepts
Recommendation 5:	Remove or minimize time constraints on exams
Recommendation 6:	Balance the difficulty of exam questions with the number of questions so students can finish the exam in the time allotted

2008; Dickson & Miller, 2005; Driessen et al., 2022), and our study adds a unique contribution by focusing specifically on biology students’ perspectives. As students in the present study shared, in-person exams permitting a cheat sheet were perceived to reduce their anxiety and improve their perception of learning biology concepts. Allowing students to use a cheat sheet may help biology instructors reduce the negative effects of exam anxiety on performance gaps for women and students of color in undergraduate biology courses (Ballen et al., 2017; Cotner & Ballen, 2017; Cotner et al., 2020; England et al., 2019; Farrar et al., 2023; Salehi et al., 2019; Salehi et al., 2021). Addressing these performance gaps requires a course-deficit approach, identifying course elements such as closed-note exams, that may contribute to equity issues (Cotner & Ballen, 2017). Further research is needed to fully explore the impact of different exam formats on reducing these gaps.

While students in the present study shared that having open notes or cheat sheets on exams supported their learning of biology concepts, the literature on how the availability of notes impacts

assessments in biology courses is inconclusive. For example, Sato et al. (2015) found no difference in the performance of students who took an open-note quiz or closed-note quiz in biology courses while Moore and Jensen (2007) determined that long-term retention was reduced with open-note exams in introductory biology courses compared with closed-note exams. Effective exam preparation, whether through creating detailed notes for open note exams in introductory biology courses (Driessen et al., 2022) or producing high-quality cheat sheets with strong organization and rich detail (Block, 2012; Gharib et al., 2012), has been associated with higher exam scores. As recommended by our study participants, biology instructors might consider providing a clear and structured study guide to help students prepare exam-specific notes and cheat sheets, ensuring that the creation of these materials becomes an effective part of their study process and exam preparation.

Students reported the highest anxiety levels when using the remote proctoring software LockDown Browser with their video camera on. Notably, similar levels of high anxiety were reported for exams proctored with LockDown Browser alone (without video monitoring) and in-person proctoring, suggesting that the video component may be a key factor of increased anxiety. This aligns with findings by Terpstra et al. (2023) who noted that students perceive certain types of monitoring—such as video recordings of their room and tracking eye movements—as invasive and anxiety-inducing. Similarly, STEM students reported having higher anxiety when using LockDown Browser for online exams and quizzes (Pennino et al., 2022). Students enrolled in online science courses during the pandemic shared their anxiety was exacerbated due to video surveillance, driven by fears of being unfairly flagged for academic misconduct if a family member made a noise or they simply looked away from the screen to think (Mohammed et al., 2021). Taken altogether, these insights suggest that eliminating video surveillance during online exams could be one way to alleviate some of the stress students experience during online proctoring.

Relying on video surveillance proctoring methods may exacerbate student anxiety and can be viewed as a course-deficit approach, as remote proctoring software is used to maintain academic integrity and prevent cheating. This method focuses on controlling student behavior rather than addressing structural issues in course (or exam) design that may promote academic dishonesty. As an alternative, biology instructors could consider designing

online exams to maintain academic integrity with a variety of strategies, such as using question banks, randomizing question and answer order, including honor statements, and restricting the time on specific questions (Balasubramanian et al., 2020; Clark et al., 2020; Manoharan, 2019; Olt, 2002; Wilhelm et al., 2022). In online chemistry courses using these exam design strategies, students performed similarly to students who took the exam in-person (Hilaire & Franco, 2023), suggesting that non-invasive methods of maintaining academic integrity can be effective without inducing the heightened anxiety associated with surveillance-based proctoring.

Beyond adjusting exam types and proctoring practices, many students in our study expressed that removing or minimizing time constraints during exams could help reduce their exam-related anxiety. However, implementing such changes in undergraduate biology courses may prove challenging. In our exploratory study, students offered two potential suggestions for reducing anxiety: (1) providing a variety of exam formats, including take-home exams; and (2) ensuring a balance between the difficulty of the questions and their number so that students have sufficient time to complete the exam within the allotted time. Take-home exams allow students to work at their own pace and may reduce the pressure of completing exams within a limited timeframe, which has been found to decrease students' anxiety (Bengtsson, 2019). Additionally, take-home exams can be designed to evaluate students' higher-order thinking skills by focusing on application and analysis rather than rote memorization (Bengtsson, 2019). Notably, students in an online chemistry course reported that take-home exams deepened their learning of course concepts (Jacobs, 2020). In courses that maintain time-limited exams, biology instructors may consider ensuring that the difficulty and length of the exam are appropriately balanced to fit within the time constraints, as students in our study suggested. Factors such as handwriting speed (Connelly et al., 2005) and student identity (i.e., students with disabilities, English language learners) (Gernsbacher et al., 2020) can all impact undergraduate students' ability to perform well on exams with time constraints. Biology instructors may consider piloting exams that use time-constraints with a teaching or learning assistant to solicit feedback.

Study Limitations & Future Directions

Our exploratory study suggests that students' exam-related anxiety is influenced by exam types, proctoring practices, and time constraints, and that students' recommendations could provide insight into improving their experiences when taking exams in undergraduate biology courses. However, there are limitations in our study worth noting. First, the study had a low participation rate at 14%, resulting in a smaller sample size likely due to students being invited to participate in the study during the summer when emails are checked less frequently. This smaller sample size impacts the generalizability of our findings to other contexts. Despite this limitation, we found salient patterns in our data with students preferring in-person exams with a cheat sheet as they reported this exam type mitigates anxiety and supports their perceived learning of biology concepts. Second, while some students may have reported anticipated rather than experienced anxiety, they had the option to select "Not Applicable" for an exam type they had not encountered. During survey validation, 10 students confirmed that this option was understood as indicating no prior experience with that particular exam type. However, we acknowledge that the survey did not explicitly ask students to confirm their prior experience with each exam type. Third, we recognize that factors beyond exam format,

such as differences in instructor mindset and language, exam design, question difficulty, or classroom environment, may have influenced students' anxiety levels. While these variables were not explicitly controlled for in our study, future research could explore how such instructional differences interact with exam modality to shape student experiences. Fourth, this study was conducted at a single institution and focused on undergraduate biology courses. Future studies could expand on these findings by investigating undergraduate students' perspectives and recommendations for mitigating exam-related anxiety at other institutional contexts (e.g., community colleges, minority-serving institutions) and across scientific disciplines. Additionally, future research could empirically test how various exam types impact students' long-term retention of biology concepts.

○ Conclusions

As the field of biology continues to face challenges in recruiting and retaining diverse students (Hatfield et al., 2022; National Science Foundation, 2023), rethinking exam formats could play a critical role in fostering more inclusive learning environments. In our exploratory study, we found that undergraduate biology students in our sample preferred in-person exams with cheat sheets, as they perceived these formats reduced their anxiety and enhanced their perceived learning of biology concepts. This is particularly relevant given the performance gaps that have been documented for women and students of color in undergraduate biology courses due to exam-related anxiety (Ballen et al., 2017; Cotner & Ballen, 2017; Cotner et al., 2020; England et al., 2019; Farrar et al., 2023; Salehi et al., 2019; Salehi et al., 2021). To address these gaps, we suggest that biology instructors consider more flexible assessment formats, such as open-note exams or exams with cheat sheets, which may help reduce anxiety and promote more equitable learning environments for all students. Shifting away from a student-deficit mindset that assumes students need close monitoring to demonstrate their knowledge could further support the success of all students. Given our study's small sample size, further research is needed to explore how these approaches can be applied in diverse educational settings.

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