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Virtual Lab Implementation Model Predicts STEM Future Plans: Insights from Contemporary Science Courses in Higher Education, Updated November 2023

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Abstract

Using a mixed-method approach, researchers examined college instructors' use of a virtual lab simulation library, Labster, students' perceptions of the simulations on their learning and future STEM plans, as well as data from the library to explore patterns of lab use and quiz scores. A detailed look at Contemporary Biology I and Biology II quiz scores found that virtual lab use was more regular during the second year of implementation, and students' quiz scores significantly improved, with fewer quiz attempts. An exploration of DFW rates found a 34% decrease of DFW rates across all three pairs of Biology I and Biology II courses, although it did not reach statistical significance. Outcomes of the student survey revealed that when virtual lab assignments occurred before the in-person lab, students were four times more likely to "Plan to work in a STEM field" and over five times more likely to "Plan to take more STEM courses" when compared to students who used the virtual labs at other times. To better understand the difference between a student confident of a future in STEM to one unsure, a sense of belonging to the science community at the university was a distinguishing factor. All results with the exception of the course grades analysis were peer-reviewed and published in the EdMedia + Innovate Learning conference proceedings in July 2023. These findings have important implications for implementing virtual lab simulations to increase student performance, decrease DFW rates, and support continued STEM course enrollment.

Keywords: virtual learning, STEM, higher education, technology, enrollment, Labster, simulated labs

Introduction

Since returning from the pandemic, college instructors nationwide have been challenged by a lack of student engagement. Leaders of programs in science, technology, engineering, and mathematics (STEM) fields have experimented with innovative technologies for many years to increase student engagement and interest (e.g., Baiyun Chen, Bastedo, & Howard, 2018). Integrating virtual science lab tools could be critical in leveraging technology to enhance student engagement and improve learning outcomes in STEM disciplines (e.g., Van der Kleij, Feskens, & Eggen, 2015). This paper explores student and instructor perceptions of Labster, a virtual science lab tool, and its impact on student engagement levels and enrollment outcomes.

Understanding the factors influencing student engagement and learning outcomes is crucial for improving pedagogical practices and creating effective learning environments. While student engagement refers to the enthusiasm, interest, and involvement students exhibit during their learning experiences, their perceived engagement may or may not correlate with their long-term STEM involvement goals. For example, leading student engagement researcher Vincent Tinto believes engagement is an overall indicator of student well-being (Tinto, 2022). On the other hand, the productive struggle students go through when diving more deeply into understanding the science concepts and relationships among scientific ideas (instead of simply finding an answer) may be frustrating even though the process of learning may lead to higher grades (Townsend, Slavit, & McDuffie, 2018).

Given this knowledge, **in what ways can instructors use Labster to help students engage in their STEM coursework in a way that promotes the learning process?** Based on student feedback, higher levels of support are perceived in contexts where instructors use active learning techniques and offer collaborative learning opportunities in their classroom instruction (Umbach and Wawrzynski, 2005). Furthermore, active learning plays a significant role in STEM courses, where it has been found to significantly reduce the performance gap between students from well-resourced and under-resourced educational backgrounds (Ballen et al., 2017). By examining instructors' use of and student perceptions of using virtual science lab tools, this study aims to contribute to the growing body of research on technology-enhanced learning and provide valuable insights for educators and administrators seeking to optimize student's class engagement and longer-term science learning outcomes in STEM higher education.

Research-Based Design

While Labster designers were inspired by inquiry-based learning, which was shown to be very effective in science classrooms (Aktamis et al., 2016), the development team recognizes that not all learners will have equal experience and comfort with a virtual environment. Labster's simulations allow multiple entry points to help orient students to the space and tools. Learners start simulations with explicit lessons, explanations, and demonstrations or learn through an interactive inquiry-based learning approach. Responding to research on motivation (Deci & Ryan, 2001), Labster designers set all clocks in the lab at 8:00 and removed any sense of deadlines, which would lower a student's intrinsic motivation. By incorporating choice at the start and throughout inquiry-based learning, students learn independently and at their own pace, increasing their autonomy and independence (Vries & May, 2019).

A later addition to Labster was Dr. One, a virtual lab assistant, developed to show student users how to complete a task before trying it themselves and remind students about lab safety. Research suggests that student learning with virtual helpers or "pedagogical agents" positively affects learning outcomes (Schroeder & Craig, 2021), perhaps by reducing the cognitive load on the learner. This is particularly true when the pedagogical agent allows students to experience worked examples in combination with their own problem-solving (McLaren & Isotani, 2011). With this research finding in mind, Labster's theory of change details how access to simulated lab experiences in a safe, private, expert-led, and untimed environment increases students' time, comfort, and opportunity to explore and learn scientific concepts.

Product Description

Virtual labs are interactive science simulations enabling students to engage in laboratory activities from their devices. Labster's virtual laboratory and science learning platform provides faculty, administrators, and students with a 24/7 science campus in the cloud. Labster's simulations are interactive learning environments that place the student in a central, decision-making role where they are challenged to apply their skills to solve problems within the context of a story. All the action takes place inside a 3D model of a real biology, chemistry, or physics laboratory, but with a unique twist: the laws of time and space can be deliberately broken to demonstrate the principles that make real science work.

As they progress through each Labster simulation, students practice lab techniques, visualize scientific concepts, and test their newly acquired knowledge. The simulations include an element of gamification that requires students' active participation via a pedagogical agent in the form of a virtual character that motivates, supports, and encourages them with questions, feedback, hints, and explanations.

Labster's catalog includes over 300 virtual lab simulations in biology, chemistry, and physics. Each simulation is a guided activity with embedded quizzes to empower students with feedback so they can assess their own understanding. For instructors and administrators, there is a performance dashboard to track student progress, identify areas where they need additional coaching and reinforcement, and supplemental resources to help scaffold learning, including lab manuals, lab report templates, explainer videos, theory pages, and graphics.

Virtual lab simulations complement lectures, readings, and hands-on lab activities. Students can directly relate what they learn in simulations to their course content. Learning with virtual lab simulation is game-like and could support student motivation. Combined with pedagogically sound design, virtual lab simulations seek to create the conditions under which students become more active participants in their learning.

Study Methods

A large public university in Texas partnered with LXD Research to conduct the study. The Instructional Design team brought Labster as a tool during the pandemic, and eight instructors continued using the program to supplement and complement in-person lab instruction. To better understand the use of Labster, researchers analyzed product data from Labster, conducted two student surveys, and interviewed instructors.

Instructor Interviews

The leaders of the university's instructional design team sent an invitation to the instructors using Labster to complete a brief survey with questions about their usage and implementation of Labster in their classrooms. In this survey, instructors were allowed to opt in for a short interview with a research team member. Four instructors opted in to be interviewed for 60 minutes. All four interviews took place on Zoom and were subsequently transcribed and analyzed for common themes and suggestions. Courses taught by the interviewees included: General Chemistry 1, General Chemistry 2, Organic Chemistry 1, Contemporary Biology (i.e., 'science for non-biology majors'), Biosciences 1, Exercise Physiology, and Exercise Nutrition (graduate course).

Student Surveys

Two brief surveys were administered to undergraduate students at a large university in Texas. The leaders of the university's instructional design team sent the students invitations to complete the surveys. The survey includes a 10-item Science Engagement Scale, which will be validated in the larger research project. One survey was administered as a pre-course (start of semester) survey, while the other was administered as a post-course (end of semester) survey. Both surveys included questions about students' opinions and perceptions of using Labster in their science courses. This report focuses on the post-course survey. A total of 188 undergraduate students completed the post-survey. (A larger response rate was likely associated with a $10 Amazon gift card as an incentive for completing the survey.) Twelve students did not use Labster but still answered a few questions in the survey.

User Data Description

Labster data reflected 40 unique courses utilizing the tool across two years, two semesters, and one summer each (Summer 2021 through Spring 2023). Information about each student's attempt for each simulation, including their quiz scores, was analyzed for patterns. Students were given a new identification number each time they enrolled in a class; therefore, student experiences could not be followed over time. Instead, cohorts of students could be compared (e.g., students who took Biology I in Fall 2021 vs. Fall 2022) to determine whether usage differed from year 1 to subsequent years (i.e., Year 2 or Year 3). Due to the course scope and sequence for science majors, it could be inferred that nearly all students in advanced classes took the prerequisite the semester before (e.g., students who took Biology II in Spring 2023 were in Biology I in Fall 2022).

Course Grades

The university partner provided LXD Research with course enrollment and grade summaries across multiple years. Since the user research analysis focused on Biology I and II, these courses are the ones of focus for this report. Data included the number of enrolled students, percent Hispanic or Latino according to IPEDS standards, percent female, percent final grades A or B, and percent final grades D, F or withdrawn (DWF).

IPEDS categorizes Hispanic or Latino excluding all international students since those who identify as Hispanic or Latino and are international students will only be classified as "International." Additionally, "No Credit" (NC) grades were omitted, but the students were counted in non-grade fields since it is not clear what lead to NC grades and labeling them as DFW is likely improper.

Results

Instructor Interview Themes

The four instructors from three departments provided insights into how science courses were structured. For example, introductory or Level I courses may be half-filled with science majors. In contrast, advanced courses or courses on targeted topics such as Kinesiology may be nearly all science majors (General Chemistry I is a prerequisite for General Chemistry II, etc.). All of the instructors mentioned that the curriculum for courses was pre-established according to a standard textbook in the field and Labster was incorporated as review or to supplement learning. The course lab component was typically three hours a week for the semester and Labster was typically incorporated as review or supplement to the in-person lab. For courses that did not have a lab component (e.g., Exercise Physiology and Exercise Nutrition), Labster was incorporated into the course as a supplementary tool to learn assessment techniques.

Instructors incorporated Labster at varying rates and times, ranging from 2 virtual labs per course to 12 labs per course. All four instructors assigned Labster virtual labs to be done individually, while in-person labs combined individual and group work. Half of the instructors said it was their first year using Labster.

Two instructors had a very good understanding of how to use Labster to support learning and found it very beneficial. They agree that it helps both science majors and non-science majors grasp an overview of a concept for an experiment or technique, even if they've never performed it. One explained,

> "*I loved it. The experience, the students really enjoyed it. They didn't get a 100% the first time through, so they had to struggle a little bit. Some of them didn't get a 100% the fourth or fifth time through. So it was clearly something that wasn't something where you just sat down, clicked a couple buttons and got through it. They were actually challenged, they actually had to think. And the students enjoyed it too, when I asked. And I think it was a great experience. I'll keep using [Labster] and what I'm considering doing is extending it out to the lecture course and giving some homeworks with those as well. I just haven't gotten to that point yet.*"

The other instructors still were exploring the tool and needed to spend more time to figure out how to incorporate it more effectively.

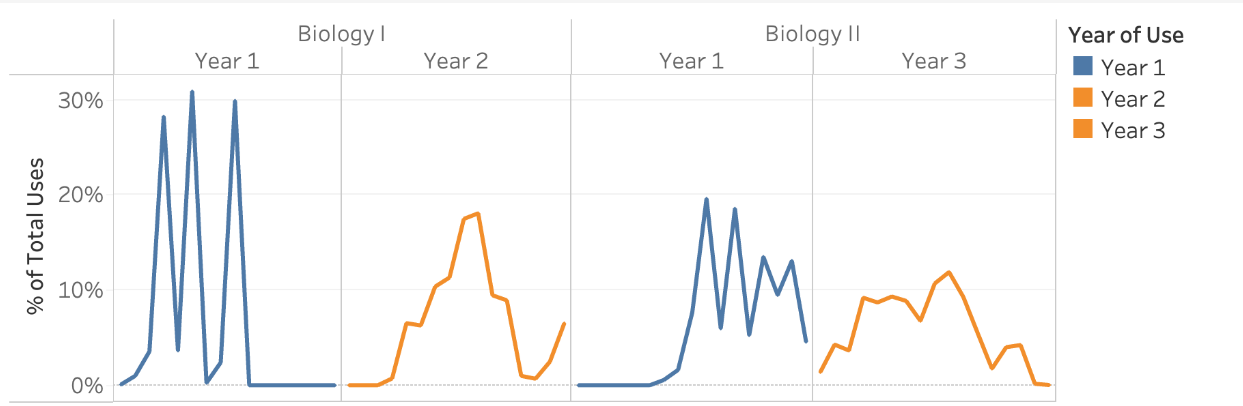
While individual instructors mostly reported positive experiences using Labster with students, three out of the four interviewees did not know that seven other instructors also used Labster. Because instructors did not share ideas or experiences with each other, a range of implementation models were identified. Instructors assigned Labster after a lecture content, before the lab to preview the experiments or concepts, or after the lab to review what was covered. Instructors also mentioned using them during the lecture, between challenging in-person labs, or as something extra over spring break.

In sum, all four instructors agreed that Labster was an engaging and hands-on tool that provided students with the ability to practice simulations and experiments that stimulated their learning.

User Data Analysis & Results

Initial exploratory analysis of the Labster simulation data revealed a change in implementation patterns from Year 1 to Year 2 (Fall) or Year 3 (Spring). The graphs below show the % of all lab simulation completions by week across each semester each year. From week to week, Year 1 shows inconsistent use of Labster throughout the semester, with multiple weeks of greatly reduced use. Subsequent years show a pattern of use that suggests less use during the first and last weeks of class, but more consistent use throughout the weeks in between.

Figure 1. Weekly Usage Rates by Course and Year of Use*



*Note: The university started using the program in Spring 2021 (with Biology II). In the graph above, Year 2 of Biology I is immediately followed by Year 3 of Biology II.

To determine the consistency of use, we calculated the standard deviation to measure the variance (i.e., volatility) difference in the number of attempts per week across Year 1. We compared the same metric with Year 2. In Year 1, standard deviations were 9.0%, compared to 5.0% standard deviation in Year 2, indicating less consistency of use during Year 1. The difference was significant $t(70) = 14.1$, $p < .001$.

After identifying this implementation change, student behavior and performance were reviewed. Contemporary Biology was chosen for this deeper dive investigation because it is a course for non-majors and a prerequisite for many science majors. Student experiences in Contemporary Biology I could impact their choices about joining or remaining in the STEM pipeline (as evidenced by their enrollment in Biology II). Looking to see changes in student scores from Year 1 to Year 2 could help answer this question and provide insights on how to support the STEM pipeline with virtual labs. Because the Labster simulations were the same and the syllabi were the same across the two years, student performance would provide evidence that the implementation patterns were not just different but were more effective. Results showed that student scores in Year 2 were significantly higher than in Year 1 ($t(2622) = 21.4$, $p < .001$), and students earned those higher scores in fewer attempts ($t(2622) = 17.4$, $p < .001$), as shown in Table 1 below.

Table 1. Bio 1 Courses: Comparing First Year to Year 2

Bio 1	Responses	Students	Averages	Significance	Effect Size
Year 1 Avg. Score	1455	408	69%	P < .001	0.84
Year 2 Avg. Score	1169	324	90%		
Year 1 # Attempts	1455	408	2.0	P < .001	0.68
Year 2 # Attempts	1169	324	1.2		

Conducting the same analysis for Biology II showed different results. Biology II is the next level course in the scope and sequence, and students choose to continue their journey in the STEM pipeline. As indicated by the sample size difference, Labster was not used by as many Biology II instructors in Year 1 (and it wasn't used as often) compared to Year 3. The Year 3 students, however, used Labster in Biology I the previous fall. Table 2 shows that, in terms of performance, students had significantly higher scores in Year 3 compared to Year 1 ($t(881) = 13.2$, $p < .001$), even though they had the same number of attempts (i.e., they performed better the first time they tried a lab). The combination of instructor experience and student experience resulted in even better results. It is also relevant to note that enrollment retention from Biology I to Biology II was quite high at 66%.

Table 2. Bio 2 Courses: Comparing Year 1 to Year 3

Bio 2	Responses	Students	Averages	Significance	Effect Size
Year 1 Avg. Score	80	34	73%	P < .001	1.55
Year 3 Avg. Score	803	215	93%		
Year 1 # Attempts	80	34	1.2	P = .903 (n.s.)	n/a
Year 3 # Attempts	803	215	1.2		

Course Grade Results

The course performance data mimics the trends seen in the program's assessment scores. Contemporary Biology Courses from Spring 2021 to Spring 2023 were organized into pairs and course levels (I and II). Each section was compared to the subsequent section of that same class, offered one semester later. In two cases, the spring class was compared to the following fall and in one case the fall was compared to the following spring. While the instructors in 2021 course pair were unique, the course pairs in 2022 and 2023 had at least one instructor that was the same in each course. The percent of students Hispanic and Female were relatively consistent did not show any trends relative to time or course type.

Table 3a. Course Pair Descriptions

	Semester	Number of Student Records	% Hispanic	% Female
Pair 1 -Bio I	Spring 2021 - Fall 2021	349	64.92%	67.65%
Pair 2 - Bio I	Spring 2022 - Fall 2022	248	58.48%	58.32%
Pair 3 - Bio II	Fall 2022 - Spring 2023	153	65.12%	64.67%
Total		750	62.84%	63.55%

In examining the trends of course grade outcomes for these students, a clear trend emerged. The proportion of students with AB grades in Biology I were statistically higher in Fall 2021 than Spring 2021, improving from 71% to 83%, a 12-point bump (χ^2=4.07, p=.044). The second year of Bio I showed a similar trend, although it did not reach statistical significance. Biology II performed similarly in both semesters for students at the top of the class (Table 3b).

Table 3b. Course Pair Changes in AB Grade Rates

	First Semester	Second Semester	AB Grade Difference	% Increase
Pair 1 -Bio I	70.75%	83.17%	12.42%	18%*
Pair 2 - Bio I	68.46%	72.73%	4.27%	6%
Pair 3 - Bio II	63.79%	63.44%	-0.35%	-1%

* *p<.05*

For course persistence (not W, "Withdraw") and pass rates (grades that are not D or F), the course's DFW rates declined in the second semester of each pair, matching the trend of Labster quiz score increases over time. Alternatively, that pair's DFW rate decreased from 10.88% to 5.45%, a 5-point decrease. Improvements on both ends of the grade spectrum speak to engagement and improved enrollment retention. Although it did not reach statistical significance, an average of 34% decrease in DFW rates across all three pairs provides promising evidence for the effectiveness of Labster in increasing student engagement and learning.

Table 3c. Course Pair Improvements in Course Persistence and Pass Rates

	First Semester	Second Semester	% DFW Difference	% Decrease
Pair 1 -Bio I	10.88%	5.45%	5.43%	50%
Pair 2 - Bio I	14.77%	11.11%	3.66%	25%
Pair 3 - Bio II	25.86%	18.47%	7.39%	29%

Student Survey Data Results

Connecting the student survey with the patterns above, we can now see how the Year 2 implementation model impacted students' perceptions of learning and future STEM course and career plans. Instructors could assign Labster use in various ways, and students can access the labs anytime. While about half of the students surveyed used Labster before doing a lab in person (57%), other students used Labster after the lab or to study before an exam (14%) or some other way (17%). A fourth group of students used Labster multiple times throughout a course, some combination of before and after the lab, before the exam, and in other ways (13%).

Analyses revealed a positive predictive relationship between the implementation model and outcome measures covered in the survey. For example, students who used Labster before the lab were significantly more likely to indicate they would take additional STEM classes than those who used other models ($t(184) = 4.3$, $p < .001$). Likewise, students who used Labster before the lab were significantly more likely to indicate they plan to seek a job in a STEM field ($t(184) = 4.1$, $p < .001$). For further details, please see Tables 4a and 4b.

Table 4a. Planning to work in a STEM Field: Comparing Not Before Lab to Before Lab

Work in STEM?	N	Percentage Plan To Work In STEM	Significance	Effect Size	Odds Ratio
Not Before Lab	68	53%	P < .001	.63	4.0x
Before Lab	118	81%			

Table 4b. Taking more STEM courses: Comparing Not Before Lab to Before Lab

Plan To Take More STEM Courses?	N	Percentage Plan To Take More STEM Courses	Significance	Effect Size	Odds Ratio
Not Before Lab	68	71%	P < .001	.66	5.4x
Before Lab	118	93%			

On the other hand, there was no significant difference between implementation models on **students' perceived impact of Labster** on the decision to take future courses or on how much they learned during the course. Nearly all students (96%) said they learned the same amount or more by having Labster as part of their coursework. One-quarter of students credited Labster for learning a lot more. By conducting this study using a mixed-method approach, we uncovered nuances that would have been difficult to see by doing the survey alone. While students' voices are important to make decisions about education tools and how to implement them, a survey alone is not enough to fully understand how a tool may relate to students' future STEM involvement.

Sense of Effort vs. Sense of Belonging

Understanding the factors that differ between a student saying, "Yes, I plan on taking a future STEM course" or "Work in a STEM field" and those who say, "Maybe…" can be helpful to inform program design changes. This survey allowed for such an exploration. The ratings for students who responded "Yes" were similar to those who responded "Maybe" on the items related to their effort and depth of thinking during science classes. When it came to their sense of belonging with the science community at their school, however, the "Maybe" students rated themselves as feeling less included than the "Yes" students. These differences between "Maybe" and "Yes" respondents were statistically significant for students who planned to take more STEM courses ($t(171) = 3.5$, $p < .001$) and students who planned to work in STEM fields ($t(153) = 2.8$, $p < .01$). This is an area where colleges could target programs and interventions to increase a sense of belonging in the community using the tools they already have. A subsequent paper will present additional analyses of the STEM Engagement Scale and the relationship between plans for a future in STEM and other aspects of science engagement.

From the instructor's perspective, only one of four instructors interviewed were aware that another faculty member from the same department was using Labster in their courses. This instructor was able to obtain troubleshooting and quick setup assistance from the other instructor. The remaining instructors were unaware of any other faculty members using Labster in their courses, of which there were seven others. This is an opportunity for the instructional design teams at colleges and universities to establish a community of Labster users who can explore new ways to incorporate the tool in their classrooms and share resources.

Discussion and limitations

Previewing information and understanding how the lab will go can positively impact student outcomes as students learn what to expect. Knowing what to expect during the lab enhances students' confidence, which is related to self-competence, one of the three pillars of intrinsic motivation. This study shows that simulated virtual labs can be an effective tool for previewing this information and students attributing the labs to greater learning outcomes.

"*The simulation is very valuable because it allows them to get kind of a hands-on experience. Doing the experiment before they get into the lab and try for the first time. That's the main, I guess, that's the main strength of Labster as to why I use it in the lab course,*" an instructor explained.

In cases where students struggle with an in-person lab, they may be asked to repeat it and progress through the lab more quickly the second time. By previewing the lab beforehand, in-person experiences may go more smoothly the first time, resulting in improved outcomes and eliminating the need for repeating them. The virtual lab allows for infinite attempts, and evidence from this study shows that students need fewer attempts to get the same high scores (or even higher scores) over time. Not only does this preview keep the lab's content fresh in their minds, but survey results also suggest that students attribute their success to the in-person lab experience. These improvements to the overall course experience were likely associated with students' increased likelihood of planning to take more STEM classes or work in a STEM field.

Receiving immediate feedback during the virtual lab can also increase the student's awareness of their own learning. By receiving real-time grading and the ability to repeat the labs for higher grades on their own schedule, students can see their progress and reinforce their understanding, which is especially helpful for students who need to be exposed to information more than once. Doing it at their own pace could also allow them to engage in inquiry by finding and using additional resources, such as vocabulary, without the time constraint of being in a classroom. As a result, there may be an increase in scientific literacy. It is worth noting that although not all students complete every task assigned, all students actively participate in the labs. As stated by an instructor, *"Not all of my students do the required quizzes that I post. Right? But all of my students did the computer labs. So that to me, says they're at least responding positively to that."* This aligns with the concept of the teacher as the 'guide on the side,' facilitating learning while allowing students to process information according to their individual styles, making learning more relevant.

Students' performance in science courses has been identified as a pipeline leak in the STEM career pathway. Specifically, STEM introductory courses disproportionately weed out underrepresented minority (URM) students (Hatfield, Brown, & Topaz, 2022). In their study, Hatfield et al. (2022) found that out of all female Hispanic students, the majority subgroup in this Labster analysis, 27% had at least one DFW in an introductory science course. This percentage was nearly identical to this study's Biology II course, which was reduced to 18% in the second year using Labster. Leveraging a supplemental interactive product such as Labster is a more scalable solution compared to other more intensive instructional assessment overhauls such as "Understanding by Design" studied by Minbiole (2016). This study provides promising evidence that improved scores in Labster were associated with lower DFW rates in Biology I courses.

Longitudinal research has shown that redesigning a biology course to more tightly align lectures and labs, leveraging technology, and making learning more relevant for students can decrease DFW rates and increase grades (Uechert, Adams, & Lock, 2011). This study's limitations include the lack of a similar comparison group to compare students who did not have access to Labster. Instructors also used Labster in various ways, so future research could experiment with a more prescriptive approach to provide more control in the study. Additionally, matching students' opinions with their virtual lab scores and student enrollment data and grades from the university would be ideal to better follow students along all aspects of learning and outcomes. A quasi-experimental study using Labster would build greater understanding of its impact on higher education engagement and support of future STEM involvement.

Finally, there is an opportunity for colleges to leverage tools such as Labster to build community among instructors and between students. Research shows that first-generation college students are sensitive to even daily opportunities to experience a sense of belonging, resulting in higher engagement (Gillen-O'Neel, 2021). In this study, instructors lacked awareness of an online Labster community, and at least seven other STEM instructors were using Labster at their university. When examining the difference between a student considering a future in STEM and one who was less sure, feeling part of the science community at their school was a distinguishing factor. Labster created an online community for students and instructors during the time period when this study was conducted, creating a new tool universities can leverage to build a sense of belonging among students and instructors. This online community could also be a component to include in future studies.

Conclusion

Incorporating and implementing Labster's virtual lab simulation in college STEM courses was an enriching and positive experience for virtually all students and instructors. Among students, the use of virtual lab simulations prior to the in-person lab sessions greatly predicted their plans to enroll in future STEM coursework and STEM careers. While most students credited the labs with increasing the amount they learned, many students seemed unaware of how much using the simulations before the lab influenced their learning during the lab sessions. Instructors using Labster indicated that the virtual simulations were easy to incorporate into their courses and they were able to achieve their instructional goals. However, there is a potential to establish a stronger science community – among students to enhance their connection to this community and among instructors to strengthen their experience with Labster. In sum, incorporating virtual lab-based learning using products like Labster appears to have amplified accessibility to learning, contributed to the reduction of DFW rates, and fostered student STEM retention. Moving forward, future research can offer insights to strengthen such tools, thereby creating a more inclusive and effective learning environment for students all over the world.

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