



Impact of COVID-19 Curricular Shifts on Learning Gains on the Microbiology for Health Sciences Concept Inventory

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As a validated assessment, the Microbiology for Health Sciences Concept Inventory (MHSCI) is a valuable tool to evaluate student progress in health sciences microbiology courses. In this brief analysis, we survey MHSCI faculty users and report student MHSCI scores to determine the impact on student learning gains of the COVID-19 pandemic and subsequent quarantine in spring 2020. Although a majority of students reported moving to a fully online lecture and lab microbiology course in the spring 2020 semester, there was no statistically significant impact on student outcomes reported by the MHSCI, and by some measures, student learning gains increased in the semester students moved to online learning. Further research is necessary to determine the continuing impact of online lecture/lab courses on student outcomes on the MHSCI. Our analysis of data from spring 2020 shows that the MHSCI is still a statistically reliable measure of student misconceptions and overall difficulty scores for each item on the MHSCI was unchanged due to the pandemic.

INTRODUCTION

The Microbiology for Health Sciences Concept Inventory (MHSCI) was published in 2017 as a validated assessment to identify student misconceptions in health sciences microbiology aligned to the American Society for Microbiology's curriculum guidelines (1, 2). The MHSCI assesses topics typically covered in a non-majors microbiology lecture course as addressed in the ASM curriculum guidelines but does not account for learning outcomes unique to nonmajors microbiology courses at individual institutions using the MHSCI. Since its publication, the MHSCI has been used by instructors at over 50 colleges and universities in the United States and around the world. Instructors report using the MHSCI to evaluate pre- and postunderstanding of microbiological concepts and misconceptions, for course assessment and curriculum design, to assess learning gains, and as a measurement of course efficacy (3–5). Faculty members administer the MHSCI online through an individualized link that students access to complete the 23-question multiple-choice assessment as a pre- and posttest. The MHSCI can also provide perspective on the impact of the COVID-19 pandemic on student misconceptions and potential reduced curriculum coverage in light of the transition mid-semester to different formats.

Prior to the COVID-19 pandemic, studies comparing the efficacy of online learning in STEM courses produced mixed results. Some studies indicated that students in face-to-face lecture and lab courses performed better than their counterparts in an online modality (6), while others showed no difference in student outcomes comparing face-to-face and online modalities (7–9). One study indicated that there was no difference in postgraduate degree programs among students in online upper division life sciences courses compared with students in face-to-face modalities (10). With the advent of the COVID-19 pandemic and, for many institutions, the necessity of moving both lecture and lab course components to an online environment due to quarantine, concerns were expressed in the science education community about the impact on postsecondary science lecture and lab courses (11). Many science educators opted to shift to an entirely online modality for laboratory exercises (12, 13). There is a dearth in the literature that directly compares student learning gains in face-to-face courses with online courses in undergraduate microbiology. Efforts to assess the impact of the shift to online learning must continue in order to effectively measure student learning gains in the post-COVID era in lecture and lab STEM courses in general and in microbiology lecture/lab courses in particular.

Our research question for this study was, "What was the impact of the COVID-19 pandemic on learning gains on the MHSCI?" The null hypothesis for this study was that there would be no impact on learning gains during the spring 2020 semester. In order to answer our research question, we compared the number of students describing their course as online prior to and during the COVID-19 quarantine. We also

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TABLE I
Number of student responses to the MHSCI in each data set.^a

	Total student responses			
	Student Responses on preCOVID Pretest	Student Responses on preCOVID Posttest	Student Responses on COVID Pretest	Student Responses on COVID Posttest
2-yr institution	1,149	731	341	129
4-yr private	890	723	335	194
4-yr public	1,847	358	104	72

^a Numbers include only students who completed demographic questions and opted in to include their data in the database. PreCOVID includes students from four semesters while COVID is students from a single semester.

surveyed the community of educators using the MHSCI regarding their curricular and pedagogical shifts during the COVID-19 quarantine. Further, we compared student outcomes on the MHSCI for four semesters prior to the pandemic (preCOVID: fall 2019, spring 2019, fall, 2018, and spring 2018) with scores from the spring 2020 semester (COVID). Finally, we calculated the normalized learning gains (NLG) for the PreCOVID and COVID groups to determine any changes in learning gains between the two groups (14, 15).

METHODS

Student data from MHSCI

The MHSCI is delivered using the Qualtrics platform. Faculty register and are provided with a link to the pretest and the posttest for the concept inventory. Students use the link to access the MHSCI, no identifying information is collected from the student, and the students are provided with a code to give to their instructor to retrieve MHSCI data from the database. Students had the ability to opt out of having their data used in the national database. The number of students in each data set is included in Table I. Institutional Review Board (IRB) approval was obtained for all work involving students with the concept inventory. This study was completed in compliance with human subject IRB 141007 (Johnson County Community College).

Faculty survey on transition to online

The faculty that utilize the MHSCI were sent a request to complete a survey on how they transitioned curriculum during the Spring 2020. Fifteen faculty completed the survey. No identifying information was collected from faculty and IRB approval was obtained for work involving faculty. The survey was completed in compliance with human subject IRB 200109 (Johnson County Community College).

Statistical analysis

Anonymized and randomized data from the MHSCI were collected and stored in Excel. Data exported from Qualtrics was cleaned by removing students who opted out of data collection

and removing students who completed five or fewer questions on the MHSCI. SPSS was used to conduct *t* test comparisons of pre- and post-MHSCI tests in the preCOVID and COVID groups. Learning gains are measured using the following rubric (13): ≤ 0.3 = low learning gains; 0.3 to 0.7 = medium learning gains; and ≥ 0.7 = high learning gains. The following equation was used to determine learning gains (13): $\langle g \rangle = (\text{post} - \text{pre}) / (100 - \text{pre})$. Normalized gain results were calculated in Excel.

RESULTS

In this study, we hoped to describe the impact of COVID-19 on learning and student misconceptions during the spring 2020 semester. To answer this question, we compared student outcomes on the MHSCI for four semesters prior to the COVID-19 pandemic (PreCOVID) with the spring 2020 semester that was impacted by the COVID-19 pandemic (COVID) among students who consented to have their scores used and who completed more than five of the inventory questions.

Shifts in MHSCI student use during COVID

First, we compared overall student enrollment in online courses before and after the pandemic. In the four semesters prior to the COVID-19 pandemic approximately 10% of students self-reported as being enrolled in an online lecture course. Unsurprisingly, after the COVID-19 lockdown, 55% of students reported being enrolled in an online course (Fig. 1A). As the jump in online enrollment occurred between the pretest for spring 2020 (8.2%) and the posttest (56.8%), we conclude this jump is directly related to the COVID-19 quarantine (Fig. 1A).

To further explore how different types of institutions adapted to teaching microbiology lecture during the pandemic, we looked at shifts by institution type in both PreCOVID and COVID groups. There were some key differences seen in how different institutions shifted to online modalities. Both 2-year institutions and 4-year private institutions had over 60% of students reporting an online microbiology lecture at the end of spring 2020, while only 26% of students from 4-year public institutions indicated being enrolled in online courses (Fig. 1B).

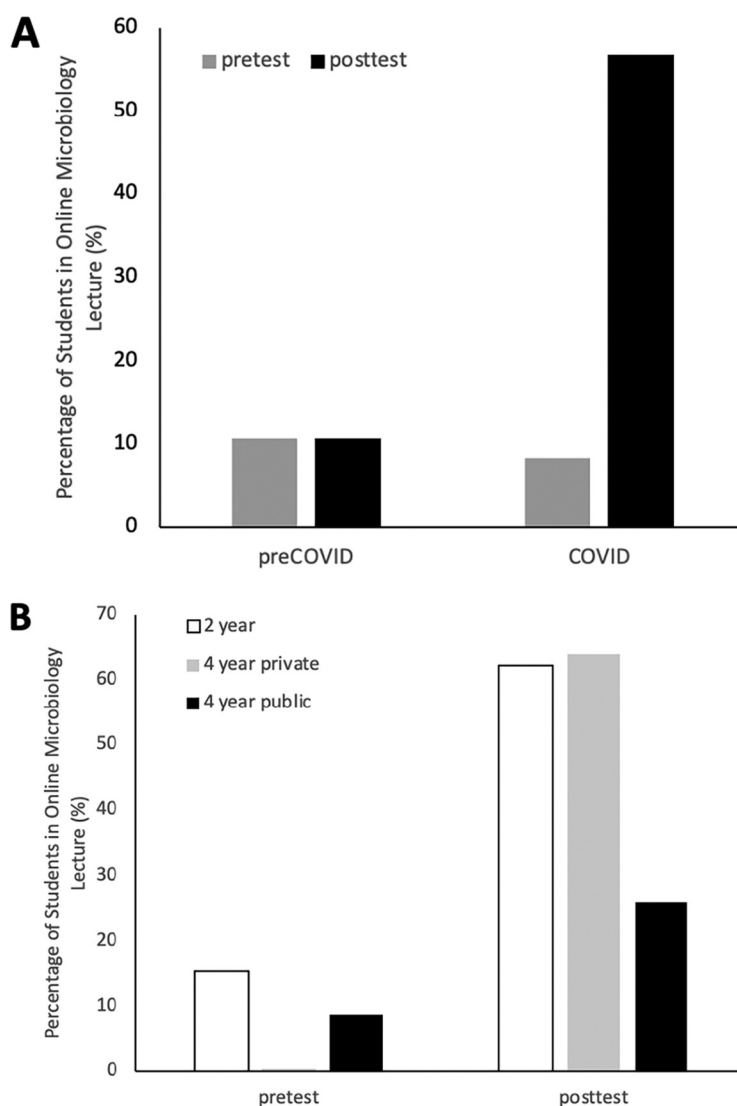


FIG 1. Percentage of all students taking the MHSCI reporting their course as online in the four semesters prior to COVID (preCOVID) or the spring of 2020 (COVID). (A) MHSCI students reporting an online microbiology lecture course. (B) The shift to online learning across institution types. Value for 4-year private pretest is 0.29%.

In addition, 2-year institutions started in spring 2020 with a larger percentage of students in online microbiology courses, and these institutions demonstrated a statistically significant increase in online delivery (15% pretest to 62% posttest). However, the largest jump to online was seen in the 4-year private institutions (0.2% to 64%). The 4-year public students reported the smallest shift to online, from 9% to 26%.

Shifts in reported lab format

The shift to an online microbiology lab is more complicated in practice. The microbiology laboratory often contains specialized equipment, biohazards, and organisms that do not transition well during a rapid shift to change course

modality. While most college-level microbiology courses include a laboratory component, in the four semesters prior to spring 2020 (PreCOVID) a small percentage of both 2-year students and 4-year public students reported not having a laboratory course (4.3% and 7.3%). During spring 2020 (COVID) the pretest data included 25% of students from 4-year public schools reporting no microbiology laboratory course and 12% of 2-year students. The percentage of students reporting no lab was unchanged in 4-year private students. We explored the incidence of online microbiology labs in the four semesters prior to spring 2020 and found that less than 0.6% of the students completing the MHSCI reported that they engaged in an online lab. This number jumped to 34% during the spring 2020 semester

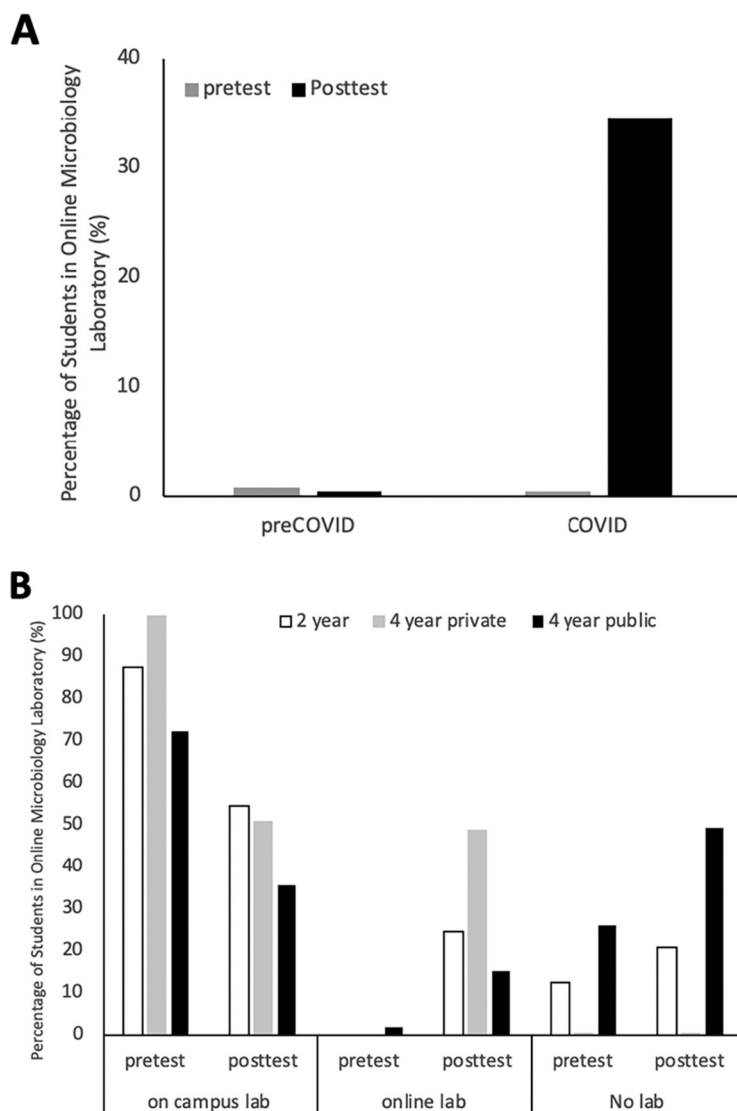


FIG 2. Students completing the MHSCI reported shifts in microbiology laboratory format. (A) Percentage of all MHSCI students reporting online laboratory format. (B) Shift in microbiology laboratory modality by institution type. There were zero student responses on the pretest indicating online lab for 2-year or 4-year private institutions. 4-year private institutions had 0.29% (pretest) and 0.59% (posttest) of students responding that they were in no lab course.

(Fig. 2A). We then analyzed how students' microbiology laboratory experience shifted at different institution types; data in Fig. 2B show the shift from pretest to posttest in modality for microbiology laboratory. While 87% of students at 2-year institutions reported an on-campus lab at the beginning of spring 2020, that number was reduced to 54% by the end of the semester with an increase in both online modality (from 0% to 25%) and students reporting no lab (from 12% to 21%). Private 4-year institutions saw the largest shift to online laboratory experiences for students (from 0% to 49%) with only 0.5% of students reporting that they did not have a microbiology laboratory course. From our data set it appears that a much larger percentage of 4-year public students (from

25% to 49%) shifted to having no microbiology laboratory experience by the end of spring 2020.

Faculty survey of modality shift

To provide perspective on the shift seen by students online versus face-to-face, we surveyed instructors who currently use the MHSCI to determine the type of online modality they shifted to in lecture (online meetings with lecture-based material, online meetings with active learning, no online meetings) and what type of lab modality they shifted to (online simulated labs, videotaped labs, or lab kits ordered from an outside company). The survey included a

free-response section for instructors to describe their unique approach to the course and lab modality shift due to the pandemic. Although 40 active instructors use the links to deliver the MHSCI through our national portal, there may be other faculty using the MHSCI; 70 faculty have requested access to the national portal MHSCI. Of the 40 instructors actively using the MHSCI, 15 faculty filled out a brief questionnaire describing the changes to their course, for a response rate of 37.5%. Instructors primarily reported shifting to online meetings with lecture-based material only (60% of respondents). There was greater variation with respect to online lab activities: 33% of respondents indicated that they held online meetings with video demonstrations of labs, 26% of respondents indicated that they held online lab meetings with virtual lab activities, 6% indicated that they used a hands-on lab kit purchased from an outside vendor. Other unique responses from instructors to the free-response section of the survey included the following:

- Asynchronous video content with data analysis.
- Ending the lab at the point of quarantine, using HHMI lab simulations
- Virtual lab activities with no online meetings
- Recorded demonstrations of lab techniques

Future analysis of online practices for the fall 2020 semester will bring greater insight into the execution of the lab component of health sciences microbiology courses.

Student outcomes on MHSCI

To study how the shift to online modality mid-semester impacted student scores on the MHSCI, student success on MHSCI questions was measured by average score (out of 23) and average item difficulty. Comparison of mean pretest MHSCI scores ($n=3,172$, $M=9.89$, standard error of the mean [SEM] = 0.064) indicated a statistically significant decrease in the COVID pretest ($n=788$, $M=9.19$, $SEM=0.11$, $t=5.74$, $P<0.001$). Observations of MHSCI scores over time indicate that fluctuations between semesters and between fall and spring are common (HMS, unpublished data). When comparing the mean posttest scores, we found no statistically significant difference between PreCOVID ($n=1,839$, $M=11.89$, $SEM=0.088$) and COVID groups ($n=472$, $M=11.94$, $SEM=0.19$, $t=-0.176$, $P=0.860$) (Fig. 3A). This suggests that, while during the spring 2020 semester students had initially lower pretest scores, they made up for this difference through the semester.

MHSCI results by institution type

With different institution types shifting to online modality at different levels, we wanted to explore whether this had an impact on MHSCI mean scores. Mean scores on the posttest MHSCI for both 2-year institutions and 4-year public institutions increased between preCOVID and COVID

semesters (11.33 to 12.08 and 12.14 to 13.22). Although not statistically significant, these data indicate no drastic change in outcome due to COVID. Meanwhile there was a statistically significant although small (less than one question) decrease in the mean MHSCI scores of students at 4-year private institutions (12.41 to 11.64, $P<0.05$) (Fig. 3B). Further data collected will be necessary to better understand the changes made at each type of institution and provide more meaningful interpretation across multiple semesters.

Looking at individual items on the MHSCI allowed us to evaluate whether there were general trends in topics or questions that may have been missed or covered differently during the spring 2020 semester. We found no significant difference in average difficulty for the MHSCI items between PreCOVID and COVID ($P=0.87$). However, these data do not account for students who withdrew from microbiology courses after the COVID-19 quarantine. In addition, there were no single items that showed a dramatic difference in item difficulty (Fig. 4). This suggests that content delivery and work to improve student misconceptions was not disrupted during the spring 2020 semester. Table 2 compares average item difficulty between the PreCOVID and COVID groups.

Learning gains on MHSCI

Normalized gain scores (13, 14) were used to determine learning gains on the MHSCI in the PreCOVID and COVID groups. The learning gains were in the low range for both groups. The PreCOVID group had a learning gain of 0.15 and the COVID group had a learning gain of 0.2. Although learning gains were low for both groups, there was a statistically significant learning gain of 0.05 in the COVID group compared with the PreCOVID group. These data indicate that during spring 2020 students had higher learning gains during COVID than in the previous four semesters.

DISCUSSION

In this article, we have addressed the following impacts of the COVID-19 quarantine among instructors and courses using the MHSCI: shifts in online enrollment, shifts in pedagogy and curriculum for laboratory components, and shifts in student outcomes on the MHSCI. There was a significant, yet unsurprising shift to online learning for laboratory sections. Prior to COVID-19, only about 10% of courses were completely delivered as a hybrid mode (online lecture, face-to-face) among users of the MHSCI. After the pandemic more than 50% of lab components moved online. Curricular delivery of laboratory sections was mixed within this group. Some instructors opted to end the laboratory section early, others shifted to online simulations, some implemented video demonstrations of lab procedures and results, and others implemented data analysis models. With the shifts in modality and the uncertainty of the semester,

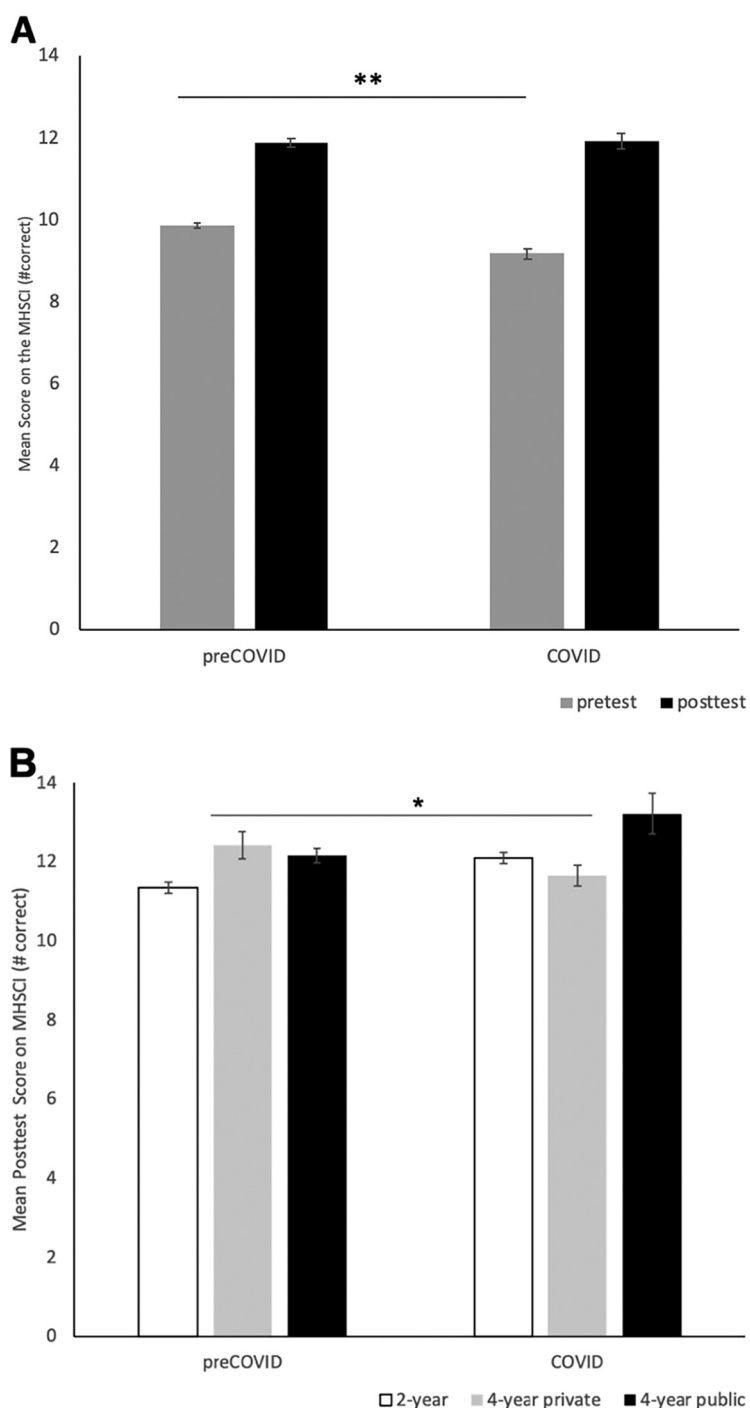


FIG 3. Student performance on the MHSCI. (A) Mean score on the MHSCI out of 23 possible correct answers. Error bars indicate SEMs. (B) Mean score on the posttest MHSCI at each institution type out of 23 possible correct answers. *, $P < 0.05$; **, $P < 0.01$.

surprisingly, there was not a statistically significant drop in the percentage of students taking the pretest versus the posttest. During the four semesters prior to spring 2020, about 60% of students who complete the pretest also complete the posttest. During spring 2020, still approximately 60% of the students took the posttest for their courses.

Regardless of the modality to which instructors shifted, student outcomes on the MHSCI remain unchanged in the spring 2020 semester as compared with fall and spring semesters prior to the COVID-19 pandemic. There was no statistically significant decrease in item score, suggesting that extraordinary effort by microbiology faculty allowed

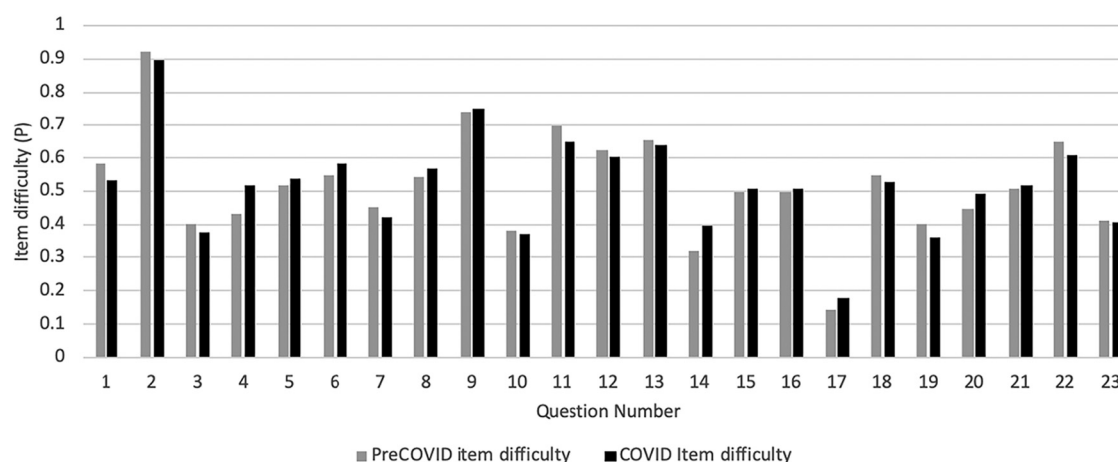


FIG 4. Item difficulty on the 23 questions of the MHSCI posttest.

the curriculum to continue despite the shifting modalities. Although learning gains were low in both groups, we found that the COVID group had higher learning gains than the preCOVID group. In general, low learning gain scores are a known issue with the MHSCI, and this will be an area for future research and study.

For postsecondary microbiology educators, the challenge remains to develop meaningful online content during the COVID-19 pandemic and quarantine. Implementation of lecture and lab sections varies from state to state and from institution to institution. The results of our survey of MHSCI users and student outcomes suggest that students' success is statistically similar with the shift to online lecture and lab compared with face-to-face and hybrid modalities prior to the COVID-19 pandemic. These results are consistent with previous pre-COVID-19 studies that showed no statistically significant differences in student success in fully online courses compared with face-to-face courses (9–11). However, further research and monitoring of student outcomes on the MHSCI will add greater depth to the insights gained from this brief analysis. We plan to conduct a follow-up study with instructors who use the MHSCI to learn more about how they adapted their courses in fall 2020 as well as spring 2021. The MHSCI will continue to be a valuable tool for individual instructors and institutions in assessing the efficacy of online lecture and laboratory components of microbiology for Health Sciences majors.

TABLE 2

Comparison of average MHSCI item difficulty in pre- and postCOVID cohorts

	Pre-COVID ^a	COVID
Pretest	0.430	0.399
Posttest	0.518	0.519

^a Pre-COVID includes the four semesters prior to spring 2020.

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