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| Research Article

Unlocking learning: exploring take-home examinations and *viva voce* examinations in microbiology education for biomedical laboratory science students

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ABSTRACT Many educational institutions transitioned to digital distance-based learning and assessment formats in 2020 due to the severe acute respiratory syndrome–coronavirus 2 (SARS-CoV-2) pandemic. This shift has often been associated with concerns about increased student cheating and heightened stress. In this study, we compared the major course assessment grades of students in a microbiology course delivered through a digital distance-based format, including a take-home examination and a *viva voce* examination during 2020, 2021, and 2022 (n = 127) with those who took the course in a traditional, live, in-person format with an in-class examination in 2019 (n = 45). Additionally, an extensive course evaluation survey was conducted to assess student satisfaction with the different course formats. In 2019, the pass rate was 27%, which increased significantly to 63% (P < 0.001) when provided as a distance-based course during 2020/2021/2022. The survey results indicated that most students appreciated the digital distance-based format and considered it beneficial for their learning. While some students found the take-home examination to be challenging and the *viva voce* examination stressful, others viewed the take-home examination as beneficial for their learning and the oral follow-up as a valuable opportunity for further learning. The combination of digital lectures and quizzes enabled students to learn at their own pace and convenience, which can lead to greater engagement and contribute to higher pass rates. Take-home examinations promote deeper learning as students must independently find answers to questions. When these examinations were followed by *viva voce* examinations, students were given the chance to elaborate on their responses, thereby gaining additional insights and reinforcing their learning during the examination process.

KEYWORDS microbiology education, biomedical laboratory science students, digital learning, take home examination, viva voce examination

Biomedical laboratory scientists (BLS) work not only in different types of clinical laboratories (*e.g.*, microbiology, chemistry, and transfusion medicine), but also in other settings, such as research laboratories and pharmaceutical companies. They perform laboratory assays on tissue samples, blood, and bodily fluids, with approximately 60 to 70% of all diagnoses based in part on the analyses performed by BLS (1). Today, BLS represent a licensed health profession in many countries, and their core competencies include carrying out laboratory work, analysis, and assessments (2). At Karolinska Institute, all BLS students start their current microbiology training at year two (fourth semester). By then, the students know each other well and are used to working both individually and in different groups. To achieve effective learning in all groups, learning must involve every member of the group. Each person should have a valid job to perform with a known standard of completion, and each

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member is invested in completing the task or learning goal and is accountable both individually and collectively (3). To achieve a good learning environment and active learning, the student-centered approach is an effective way that has been shown to increase both student learning and achievement and is associated with improved academic performance (4). Student-centered models are usually defined in opposition to teacher-centered models, in which teaching is characterized as presenting information, and those who can learn will learn. The general model of teaching should instead incorporate interactive engagement and cooperative work in place of lecturing, hence demanding greater student responsibility for learning outside of class (5). There are several ways to achieve student-centered learning, such as flipped classroom (FC) (6), for example, team-based learning (TBL) (7). In 2019, the microbiology course was given solely as a traditional lecture-based course on campus and finally assessed by a written summative in-class examination. Since the students' academic performance in this examination was poor, we decided to change the delivery method of the course to obtain more student activation. This happened to coincide with the onset of the severe acute respiratory syndrome–coronavirus 2 (SARS-CoV-2) pandemic when many courses were obliged to switch into digital distance-based learning and examination. Today, online education is accessible, flexible, and effective. However, challenges still exist with learning online, such as increased student anxiety, lack of student motivation, problems with communication, and valid examinations (8, 9). Several recommendations exist to overcome problems, such as establishing learning objectives and aligning assessments and assignments with these (10). The prevalence of cheating and academic dishonesty has increased over the recent years, and the main reason for this is believed to be the growth of online teaching (11). Academic dishonesty in online assessments can manifest in various ways, such as identity misrepresentation, where someone else takes the exam on behalf of the student, collaborating with other students during the exam and sharing answers, plagiarism, and manipulating technology by causing intentional internet disruptions to gain extra time (12). Strategies exist to overcome these types of dishonest academic behavior, and precautions can be applied, such as restricting the time allowed for the completion of an assessment, randomizing the test for each test taker, or preventing backtracking in the exam. These are ways that all can limit opportunities to cheat, although when analyzing from a student perspective, the abovementioned methods to avoid cheating are all known to cause anxiety among students and are, therefore, not recommended when designing a valid online assessment (12). Due to the challenges with academic dishonesty during online examinations, many educators implemented the so-called open-book examinations as an alternative for assessment in online education. During an open-book examination, learners have access to supportive material, being books, notes, and online materials. Studies have shown that open-book examinations stimulate students' long-term memory and can evaluate higher-order cognitive abilities. Open-book examinations can also lower learners' anxiety during assessments, thus enabling a higher performance (13). Like open-book examinations, the so-called take-home examinations both reduce student anxiety and is an excellent way to test students' higher-order thinking skills (14). It has been shown that a student spends more time conducting a take-home examination than an in-class examination. One would, therefore, conclude that take-home examinations also constitute a better learning experience, hence facilitating long-term memory. The most cited concern with take-home examinations is the risk of cheating, and it may, therefore, be good to combine take home examinations with another assessment method. A traditional form of examination is the oral examination or *viva voce* exam, in which one or more examines pose questions to the examinee (4). By using blueprints/checklists to structure the questions and by documenting the answers, it has been able to structure the *viva voce* examination and, as such, have a place in the assessment of undergraduates (15, 16). Both students and assessors consider structured *viva voce* examinations as an assessment that contributes to learning (17), even if the *viva voce* examination is also associated with increased student anxiety and stress (17, 18). The drawbacks of

the *viva voce* examinations are that they are associated with higher interrater variation and prone to unconscious examiner biases (18). *Viva voce* examinations have, therefore, mainly been suggested for use in formative situations, and it is highly important to have structured exams (19). Take-home examinations could, for instance, be combined with a *viva voce* examination, where it is possible to give direct feedback to the student (20). However, during a *viva voce* examination, it is possible to clarify questions for the student, and, when used in combination with a take-home examination, it may also enable the student to elaborate on her/his answer given in the take home examination.

Objectives

The purpose of this study was to analyze students' performances and perspectives of a switch from a live, in-person microbiology course to a digital distance-based microbiology course with a shift from an in-class examination to a take-home examination and a *viva voce* examination among second-year BLS students. The specific research objectives were to (1) compare student performances using a live, in-person course format assessed with in-class examination with a digital distance-based course format assessed with a take-home examination and a *viva voce* examination and (2) to analyze the students' satisfaction with the different course formats.

METHODS

Study design

This was an observational study involving BLS students at Karolinska Institutet, Stockholm, Sweden. It is described according to the Strengthening the Reporting of Observational Studies in Epidemiology statement (21).

Setting

In 2019, the microbiology course was given as a live, in-person format with a written summative in class examination in two parts (*i.e.*, theory and methods). In 2020, the course changed to a digital distance-based format with a take-home examination, followed by a *viva voce* examination online. Since these students had free access to all teaching and learning materials, the essay questions in the take-home examination were more extensive compared to those in the in-class examination. The *viva voce* examination was based on questions from a specific protocol and limited to 25 min per student. The timeframe for the *viva voce* examination was chosen to ensure that the students had no opportunity to find or verify answers using other sources. In 2021 and 2022, we also included a reassurance test to better screen for misunderstandings among the students. For details of the study, see Fig. 1. The microbiology course corresponds to five European Credit Transfer and Accumulation System points (corresponding to 150 study hours) and given over a 5 week period and is mandatory for all BLS students.

Participants

The participants were BLS students enrolled in the BLS program during semester four at Karolinska Institutet, Stockholm, Sweden (22). The inclusion criteria were all enrolled students during 2019 to 2022 (n = 176). The exclusion criteria were absent data. Four students dropped out and did not take part in any of the examinations. In total, the academic performance of 172 students were included.

Variables

The academic performances in the final examinations (in class examination, take-home examination, and *viva voce* examination) were the major variables.

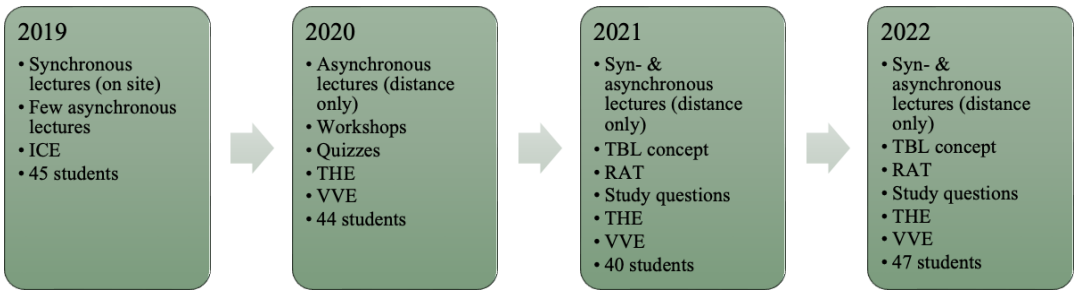

FIG 1 Delivery method of a microbiology course for BLS students between 2019 and 2022. Indicated are the type of lectures, type of teaching and learning, examination types, and number of students participating.

Data sources/measurement

In the current study, the students' satisfaction with the new course module format was evaluated through an anonymous voluntary questionnaire when the course was finished but before they had received the result of their examinations. In the questionnaire, they evaluated different aspects of the course module on a scale of 1 to 5, where one represents very unsatisfied, and five represents very satisfied. In the questionnaire, three open-ended questions were included.

Bias

The voluntary questionnaire was completed by 62 of the 172 students who participated in the course; thus, it may be biased.

Study size

The sample size was not required since all students that took part in the exam were included.

Statistical methods

Data were analyzed using Excel version 2016 (Microsoft Corp., Redmond, WA, USA) and Prism 9 (version 9.5.0, Graph Pad Software, San Diego, CA, USA). Descriptive statistics summarized the distribution and frequency of pass rate. Comparisons between groups were made by one-way analysis of variance (ANOVA) followed by *post hoc* Tukey's test. Significance was set at $P < 0.05$.

RESULTS

Student performance

In 2019, the in-class examination in microbiology was divided into two written parts, one in microbial theory and one on microbial methods. In total, 45 students participated in both the theoretical and methodological exams. The passing rate of the theoretical exam was 33%, and that for the methodological part was 58% (Table 1). In total, 27% of the students passed both the theoretical and methodological exams.

During 2020 to 2022, the course was assessed by a take-home examination and followed up with a *viva voce* examination. The passing rate in the take-home examination was significantly higher since as many as 63% of the participating students passed the take-home examination (61, 68, and 61%, respectively; Table 1; $P < 0.001$). The passing rate in the *viva voce* examination was even higher with 83% of the students that passed the *viva voce* examination (79, 84, and 86%; respectively; Table 1; $P < 0.001$). In total, 69% of the students during 2020 to 2022 passed both take-home and *viva voce* examinations ($P < 0.001$). There was a drop in the number of students that participated in the *viva voce* examinations, and in 2020, when 44 students handed in a take-home examination, only 38 of these participated in the *viva voce* examination (86%). In 2021,

TABLE 1 Academic performance 2019 to 2022[a]

Year	Type of exam	*N*	Pass	Passing rate	*P*-value
2019	ICE—method	45	26	57.8%	<0.001
	ICE—theory	45	15	33.3%	NS
	ICE—combined	45	12	26.7%	
2020	THE	44	27	61.4%	0.002
	VIVA	38	30	78.9%	<0.001
2021	THE	37	25	67.6%	<0.001
	VIVA	31	26	83.9%	<0.001
2022	THE	46	28	60.9%	<0.001
	VIVA	43	37	86.0%	<0.001
2020–2022	THE	127	80	63.0%	<0.001
	VIVA	112	93	83.0%	<0.001

[a]ICE, indicated in class examination; THE, take-home examination; VIVA, *viva voce* examination. Data are presented as numbers (*N*) and percentages. NS, non-significant.

37 students handed in their take-home examination, and 31 of them participated in the *viva voce* examination (84%). In 2022, 93% of the students that handed in their take-home examination participated in the *viva voce* examination (or 43 out of 46). Of the 15 students who did not participate in the *viva voce* examination, only one student pass the take home examination (7%).

Responses to Likert survey questions

As seen in Fig. 2A when analyzing the student questionnaire, it was evident that the course already in 2019 was considered valuable, and that the students found that they acquired valuable knowledge and skills (3.6), and even more so in 2020 (4.4) and 2021/2022 (4.1 and 3.9, respectively). There was also a high degree of agreement with the statement that "I feel that the course has contributed to me being well prepared for my future profession," ranging from 3.7 in 2019/2022 to 4.3 in 2020 (Fig. 2D). When asked whether the course was constructively aligned, from intended learning outcomes to the assessment, the students were more reluctant to say so in 2019 (3.0), whereas with the change of the course in 2020, this received a higher score (3.9). Although in 2021 and 2022, again, the student scored this statement lower (both 3.2; Fig. 2B). The same pattern can be seen in the statement "I perceive that the course has stimulated me to a scientific approach (for example, analytical and critical thinking, self-search, and evaluation of information)" (Fig. 2C), and highest rated by the students from 2020 (4.0) and lowest by the students from 2019 (3.2).

Responses to free-text questions

Examining the responses to the open-ended questions uncovered several frequently recurring, highly relevant themes (Table 2). In the theme-learning environment, the students were predominantly positive to the design of the course (2020–2022), the digital recordings, and the web-based material. As such, they found that this learning model was beneficial and enabled learning.

> "*There was a lot of reading material during the course, which was very good training for the exams. Also recorded lectures, scripts and study questions were very helpful.*"
>
> "*There was plenty of time to study while working on the take-home examination.*"

During 2019, the only positive comments from the students in the category of learning environments concerned the individual lecturers and teachers of the course. Many of the comments instead emphasized that the course was too heavy; the different topics of the course were discussed in too much detail; and the course was unstructured

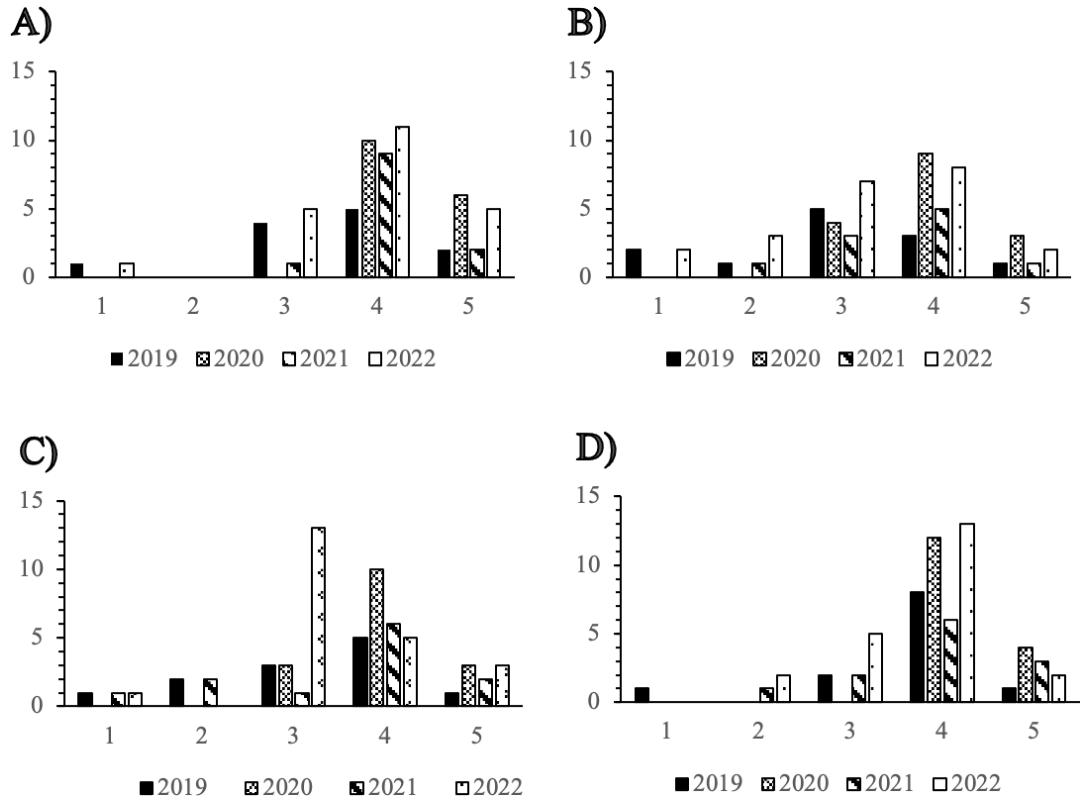

FIG 2 Responses collected from the student questionnaires for the course between 2019 and 2022. The students rated various statements about the course on a Likert scale of 1 to 5, where one represents "very unsatisfied," and five represents "very satisfied." The following statements were rated: (A) "I feel that through this course I have developed valuable knowledge/skills"; (B) "I feel there was a clear alignment throughout the course—from intended learning outcomes to examination"; (C) "I feel that the course stimulated my scientific thinking (e.g., analytical and critical thinking, self-directed research, and information evaluation"; and (D) "I feel that the course has adequately prepared me for my future profession."

and badly planned. In 2020–2022, there were students with similar views regarding the content of the course, mentioning that the course was too broad, and that the vast amount of digitally available material instead made the course too difficult and hard to grasp.

> "*All the material result in that you don't have time to study and understand, instead everything is done with minimal thought. A lot to do in a short time, I felt overwhelmed by everything.*"

In the category of fairness of examination, the comments concerning the examination in 2019 were that the exam was in too much detail, and that it was hard to plan to find time to answer all questions. In 2020–2022, the main objective concerning the fairness of examination was the fact that each student was orally examined individually with an examiner. Some suggested that the examination should either be as a take-home examination or a *viva voce* examination. In 2020, suggestions were also that the exam instead should be as an in-class examination, although this was not mentioned again neither in 2021 nor in 2022.

Regarding the theme, burden of exams, the most frequently mentioned advantage of a take-home examination was that it did serve as a good way to prepare for the *viva voce* examination, and that it was well suited for distance studies.

> "*The form of examination was also good with take home examination and orals, which was well suited for distance learning.*"

TABLE 2 Topical themes of BLS students' self-perceived responses about the courses in 2019 to 2022 (N = 62)[a]

		2019 (N = 12)		2020–2022 (N = 50)	
Category	**Subcategory**	***N***	**%**	***N***	**%**
Learning environment	Engaged teachers	4	33	6	12
	Good course design	–[b]	–	7	14
	Appreciate prerecorded lectures	1	8	16	32
	Bad structure/planning	5	42	2	4
Fairness of examination	Not corresponding to ILOs	2	16	–	–
	ICE—to complex questions	3	25	–	–
	THE—not necessary			2	4
	VIVA—too detailed			2	4
Burden of exams	Experienced anexity	3	25	4	8
	THE—too detailed	3	25	2	4
	THE/VIVA good	–	–	5	10
	VIVA stressful	–	–	4	8

[a]ICE, indicate in class examination; THE, take-home examination; VIVA, *viva voce* examination. Data are presented as numbers (N) and percentages.
[b]–, no replies.

> "The take-home exam and the study questions were a good way to practice."

Although some students found the take-home examination heavy and the *viva voce* examination stressful, others found instead the take-home examination very beneficial for their learning and the *viva voce* examination a learning opportunity.

> "*Good concept with take home examination and an oral follow-up, it gave an opportunity to interact with the teacher and elaborate on my replies in the take home examination. I was very nervous before the oral exam, but it was a pleasant surprise and for the first time I learned something during an examination*"

DISCUSSION

This study investigated if it was effective to use a combination of blended assessments with take-home and *viva voce* examinations to enhance academic performance in a microbiology course for BLS students. The specific research objectives were (1) to compare the students' performances between the live, in-person course format using in-class examination and the digital distance-based format with take-home and *viva voce* examinations and (2) to assess students' satisfactions with the different course formats. In this study, we found an enhanced academic performance with the new course concept and examination using take-home and *viva voce* examinations in comparison to the previous delivery method with lectures on site and in-class examination. In previous studies, take-home examinations have been found to promote deeper learning since a take-home examination requires students to independently research answers (14, 23). In an asynchronous setting, it is possible for a student to learn when and where it is most suitable for her/him. With a shift from synchronous live, in-person lectures to asynchronous prerecorded lectures, the responsibility to learn lies more within the student, which shifts the focus from the teacher to the student, thereby demanding a greater student responsibility and student activation (5). A student-centered approach promotes student learning and is associated with improved academic performance (24). Motivation is a key factor for learning, and, for the students to stay motivated, it is important that they find the course important. In this course, it was evident that the students found the course to be both valuable and important for their future profession already before the change of the delivery method of the course to digital learning, although the change made it stronger. A challenge with learning online is lack of motivation. In a setting

when lectures are given asynchronously online, it is, therefore, important to have regular check-ups with the students to see that they are in line with the subject and stay motivated. A possible way to do this would be seminars and formative assessments during the course. We must also consider that, although some of the questions in the take-home examination closely resembled those from the previous in-class examination, the enhanced performance observed may reflect a better constructive alignment of the course. One obstacle with online learning has been the examination with regard to the risk of cheating (11) and fairness (13). Using a combined concept with both take-home and *viva voce* examinations is an effective way to address the problem with academic dishonesty since academic dishonesty in the take-home examination will be revealed during the *viva voce* examination. From the students' point of view, there were comments on fairness both regarding the in-class and *viva voce* examinations and none regarding the take-home examination. These comments should, however, be considered with care since they are just comments from a few students who responded to the questionnaire and, hence may be biased.

One aspect of *viva voce* examinations is that they are known to induce anxiety among students (25), which was one of the comments also mentioned in the questionnaire by the students during this course. This may also be one explanation to the somewhat decreased number of students that decided to participate in the *viva voce* examination during 2020 and 2021. However, it is not possible to say with certainty that stress is the reason for why they did not participate in the *viva voce* examination as the questionnaire was anonymous. Another possible reason for not participating in an oral exam may be the lack of preparation (26), which is likely the reason for some students in this study, as indicated by the fact that students that decided to not participate in the *viva voce* examination also performed less well on the take-home examination. However, stress and perceived test anxiety may not be a drawback for the individual student since it can contribute to improved academic performance to some extent (27). Summative exams are high-stake, and the design for these is crucial; one would preferably use different ways for the assessment to increase the reliability and validity of the exam. The idea with the combination of take-home and *viva voce* examinations is that the take-home examination should function as preparatory work and stimulate student learning. It is known that take-home examination stimulates deeper learning (14), and, as such, the combination of take-home and *viva voce* examinations may benefit deeper learning. In the questionnaire, a few students made negative comments on the take-home examination, stating that the take-home examination was in too much detail. Others stated that the take-home examination was not necessary. Thus, it was evident that the concept of the course was not clear to these students, and an important factor to consider is, therefore, to explain the delivery method of the course clearly if using this type of delivery method in the future. To enable more feedback during the course, one could imagine dividing the take-home examination in parts, which would then be assessed formatively during the course. To achieve an even higher degree of student engagement, one could imagine making these take-home examination parts as peer-formative assessments that would both activate students and motivate them (28). Another aspect to consider for future use of take-home examinations is the use of ChatGPT or Chat Generative Pre-trained Transformer, a freely accessible artificial intelligence (AI) (29), and the risk of cheating. It is highly likely that students will use AI to generate their answers for the take-home examination. We believe that a different approach is needed here since we know that many students already use AI as help during their studies (30). Instead of focusing on the risk of cheating and finding ways to hinder this, we believe that it is better to help students to use AI responsibly, such as a help to formulate answers and not as a direct or sole source of information (31). By encouraging students to use AI and their student peers, it may make students critically reflect on their answers, and in combination with formative peer assessment, may result in a better understanding in microbiology since reflection promotes retention of learning. The students would then also be more prepared for the *viva voce* examination,

and, by being more prepared, they would feel more secure using a universal design for learning. This also addresses the problem that some students experienced stress before the *viva voce* examination. By shifting focus from avoiding cheating in the take-home examination to trusting the students to become reflective learners, the combination of take-home and *viva voce* examinations may be considered a robust system for assessing students in microbiology.

Conclusion

Take-home examinations foster deeper learning by requiring students to independently find answers. Pairing this with a *viva voce* examination based on the take-home examination enables students to further explain their responses and creates additional learning opportunities during the assessment. The *viva voce* examination is considered as stressful among some students. When using this model, it is also important to explain the rationale for a combined delivery method using the combination of take-home and *viva voce* examinations.

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Sophie Curbo, Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review and editing | Annica Lindkvist, Data curation, Investigation, Writing – review and editing | Catharina Hultgren, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review and editing

ETHICS APPROVAL

According to the Swedish Ethical Review Authority tool, ethical approval was not necessary for this study as this research did not involve a clinical trial nor did it collect any personal data. Participation in the survey was entirely voluntary, and only anonymous data were included.

ADDITIONAL FILES

The following material is available online.

Supplemental Material

Supplemental data (jmbe00193-24-s0001.xlsx). Results from all examinations in the microbiology course for Biomedical Laboratory Science students between the years 2019 and 2022.

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