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Exploring the Use of Videos and Virtual Simulations in College Microbiology Lab Courses: Student Perception and Pros and Cons

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Abstract: This study aims to explore the advantages and drawbacks associated with the integration of videos and virtual simulations in university microbiology lab courses, comparing them to the traditional in-person approach at North Carolina A&T State University. Utilizing Qualtrics^{XM} survey software (XM/os2), data from 190 survey responses were analyzed to understand students' preferences and perceptions. Participants were asked about their preferred learning style—traditional in-person, virtual, or a combination of both. Results indicated that 57.2% of students favored a hybrid approach, combining traditional in-person and virtual microbiology lab experiences, while 30.6% preferred in-person learning and 12.4% leaned towards virtual learning. Exploring student perceptions of lab simulations (Labster 7.25.0) and YouTube videos in comprehending microbiology lab etiquette, 65% found these resources beneficial, whereas 13.1% did not. When assessing students' enjoyment of virtual lab simulations, responses varied, with 68.8% agreeing, 18% neither agreeing nor disagreeing, and 12.8% disagreeing with the statement "I enjoyed the virtual lab simulations". This extensive exploration into student perspectives contributes insights for educators and institutions, guiding the development of effective pedagogical strategies in microbiology education amidst evolving instructional modalities. The findings underscore the significance of accommodating diverse learning preferences to enhance overall learning experiences. As educational institutions continue to work to recover from setbacks caused by the COVID-19 pandemic, results from this study will empower stakeholders to update their plans for responding to future pandemics.

Keywords: microbiology lab; virtual lab; labster; YouTube; video

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1. Introduction

Microbiology laboratory courses are essential components of college education, providing students with hands-on experiences and practical skills in the field of microbiology [1,2]. Students in the microbiology lab can carry out basic lab activities such as preparation of media, culturing techniques, staining, microscopy, biochemical tests, and selective and differential tests. In response to the COVID-19 pandemic, North Carolina A&T State University shifted to remote instruction abruptly in Spring 2020. Biology classes, including General Microbiology, switched to online with varying successes and challenges. It is extremely important to be conscious of the key features, benefits, and challenges associated with virtual/online learning and traditional in-person learning. Herein, we compared students' perceptions of traditional face-to-face lab learning versus online/virtual lab learning and compared the use of two online media platforms (YouTube and virtual simulations) as lab modules to improve student learning and confidence in microbiology labs during the pandemic in the Spring 2021 semester. Traditionally, General Microbiology lab courses

have been conducted in person, where students engage with physical specimens, equipment, and their peers under the guidance of instructors [3,4]. However, the advancements in technology have opened new possibilities for instructional methods, leading to the incorporation of videos and virtual simulations as alternative tools in microbiology lab courses [5,6].

YouTube videos are digital video content hosted on YouTube, a popular online video-sharing platform. These videos can range from short clips to long-form content and cover a wide array of topics, including entertainment, education, tutorials, vlogs, music videos, and more. Users can watch, upload, share, and comment on videos, creating a dynamic and interactive environment. In regard to microbiology labs, YouTube videos were used as a tool for students to learn about common lab equipment such as microscopes, autoclaves, pipettes, petri dishes, and incubators, explaining their functions and proper usage. For example, an aseptic technique video (https://www.youtube.com/watch?v=bRadiLXkqoU accessed on 2 June 2023) was shared with the students; they were shown tutorials on isolating pure cultures by streaking microorganisms on agar plates, antibiotic susceptibility testing demonstrations on how to perform disk diffusion and broth dilution methods to test bacterial resistance to antibiotics, and conducting tests such as catalase, oxidase, and coagulase to identify bacterial species (http://learn.chm.msu.edu/vibl/index.html accessed on 2 June 2023); and they were given step-by-step guides on performing Gram staining to differentiate between Gram-positive and Gram-negative bacteria (https://youtu.be/EdGnGKObzcI accessed on 2 June 2023 and https://www.youtube.com/watch?v=AZS2wb7pMo4 accessed on 2 June 2023). Brightfield microscopy tutorials on using a light microscope to observe stained and unstained specimens (https://www.youtube.com/watch?v=SUo2fHZaZCU accessed on 2 June 2023) were also assigned to students.

Labster was launched in 2013 and is a platform that offers interactive virtual lab simulations designed to enhance the learning experience for students in various scientific disciplines, including microbiology. These simulations provide an immersive, 3D environment where students can conduct experiments, learn lab techniques, and understand complex concepts without the constraints of a physical lab. Some examples of the virtual lab simulations that were assigned to the students included lab safety (https://www.labster.com/simulations/lab-safety accessed on 2 June 2023), bacterial isolation (https://www.labster.com/simulations/bacterial-isolation accessed on 2 June 2023), and pipetting (https://www.labster.com/simulations/pipetting-master-the-technique accessed on 2 June 2023).

1.1. Pros of Using Videos and Virtual Simulations

Accessibility: Videos and virtual simulations offer the advantage of accessibility, allowing students to engage in the learning process at their own pace and convenience [7,8]. This flexibility accommodates diverse student schedules, especially for those with other commitments or constraints [9–11].

Cost-effectiveness: Incorporating videos and virtual simulations can potentially reduce the costs associated with traditional in-person lab courses [12,13]. Expenses related to physical materials, equipment maintenance, and facility management can be significantly minimized.

Safety: Microbiology lab courses involve handling potentially hazardous microorganisms and chemicals. Utilizing videos and virtual simulations mitigates the risk of accidents or exposure to harmful substances, ensuring the safety of students and instructors [14].

Standardization: Videos and virtual simulations offer the advantage of providing standardized experiences to students [15]. Every learner receives the same information and exposure to various laboratory procedures, enhancing consistency and reducing potential discrepancies among different lab sections.

1.2. Cons of Using Videos and Virtual Simulations

Limited Hands-on Experience: One of the significant drawbacks of videos and virtual simulations is the reduced opportunity for direct hands-on experience [16]. Physical manipulation of specimens and equipment plays a crucial role in developing tactile skills, manual dexterity, and observation techniques, which may be compromised in a digital environment.

Reduced Social Interaction: In-person lab courses foster collaboration, teamwork, and social interaction among students. The use of videos and virtual simulations may limit these interpersonal dynamics, potentially impacting the development of communication and teamwork skills within the laboratory setting [17].

Technical Challenges: Adopting videos and virtual simulations requires access to appropriate technology, software, and stable internet connections. Technical issues such as compatibility problems, software glitches, or limited access to necessary resources can impede the seamless integration of these digital tools into the curriculum [18].

1.3. Student Perception

Understanding student perception is crucial in assessing the effectiveness of videos and virtual simulations as educational tools. Research suggests that student perceptions can influence their engagement, motivation, and overall learning outcomes [19]. While some students may embrace the convenience and flexibility offered by digital tools, others may express a preference for traditional in-person lab experiences. Moreover, students' perceptions may vary based on their prior experience, learning styles, and personal preferences. It is important to gather their feedback regarding the benefits and challenges they perceive when using videos and virtual simulations. This valuable insight can inform instructional design, allowing educators to tailor the learning experience and address any concerns that may arise. This manuscript aims to provide an in-depth exploration of the advantages and disadvantages of integrating videos and virtual simulations into college microbiology lab courses. By analyzing student perceptions, we can gain insights into the effectiveness of these digital tools and identify areas for improvement. Understanding the nuances surrounding the use of videos and virtual simulations will contribute to the ongoing development and enhancement of microbiology education, ensuring that students receive a comprehensive and engaging learning experience.

2. Methods

2.1. Student Recruitment

The study was approved by the institutional review board at North Carolina Agricultural and Technical State University (no. 210098). The participants were second-year Biology major students and third-year non-Biology students (nursing and animal science) at North Carolina A&T State University. Two groups of students were surveyed: 1. students (n = 54) that were taught in a hybrid format (both in-person and online), which included weekly labs for 2.5 hr that rotated the use of virtual simulation, videos, and in-person labs; and 2. students (n = 68) that were taught online only for labs using videos and virtual simulation platforms. The survey was developed by a Master of Science graduate student and was administered online during the last week of classes of the Spring 2021 semester. During the time of this survey, students had the option to attend classes in-person or online. Social distancing in the classroom was being implemented to reduce the spread of COVID-19 on campus.

2.2. Survey

The survey consisted of questions ranging from perceived learning style preference to their perceptions of online versus in-person learning. Students selected their responses from a five-point Likert scale from "strongly agree" to "strongly disagree" options. The survey was administered anonymously through the university's learning management system (Blackboard Learn 9.1, 3900.2.0). The survey questions were deployed and completed using

Qualtrics^{XM} survey XM/os2 software (a cloud-based platform for creating and distributing web-based surveys).

2.3. Statistics

All graphs were created using GraphPad Prism version 8.0 Software, Inc. California, USA. A Likert scale was used for multiple-choice questions. A Likert scale is a type of rating system that measures people's attitudes, opinions, or perceptions on a series of statements or questions. Bar graphs were used to display the percentage of students who agreed or disagreed with a specific statement. Bar graphs were also used to show the percentage of students with a specific perspective and preference.

3. Results

This study sought to investigate the pros and cons associated with the integration of videos and virtual simulations in university microbiology lab courses, comparing them to the traditional in-person approach at North Carolina A&T State University. A total of 190 responses were collected through the survey, and Qualtrics ^{XM} survey XM/os2software was employed for data analysis. Participants were queried about their preferred learning style—traditional in-person, virtual, or a combination of both. The results revealed that 57.2% of students favored a hybrid approach, combining traditional in-person and virtual microbiology lab experiences, while 30.6% preferred in-person learning and 12.4% leaned towards virtual learning (Figure 1).

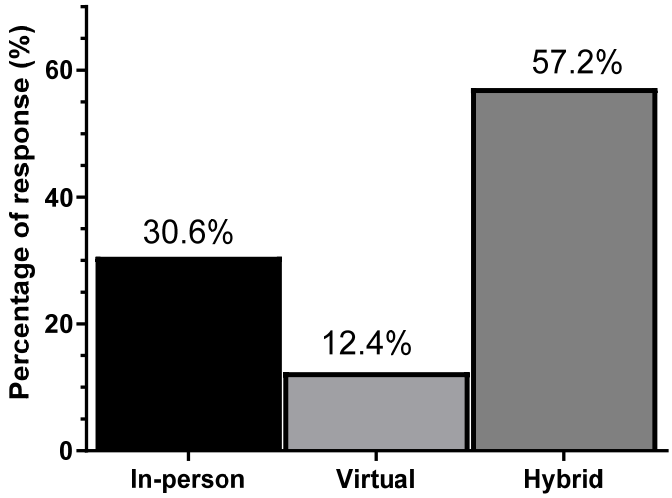

Figure 1. Students' preferred instructional mode.

In assessing student perceptions regarding the utility of lab simulations (Labster 7.25.0) and YouTube videos in understanding microbiology lab etiquette, participants were asked to express how helpful they found these resources. A majority, constituting 65% of the respondents, perceived lab simulations and YouTube videos as beneficial for comprehending microbiology lab etiquette (Figure 2). Conversely, 13.1% of participants did not find these tools helpful in understanding lab etiquette.

The investigation extended to students' enjoyment of virtual lab simulations in the microbiology lab. Using a Likert scale, participants were asked to rate their agreement with the statement "I enjoyed the virtual lab simulations". The responses indicated that 25.4% agreed, 43.4% somewhat agreed, and 18% neither agreed nor disagreed. In contrast, 5.4% strongly disagreed and 7.4% somewhat disagreed with the statement (Figure 3).

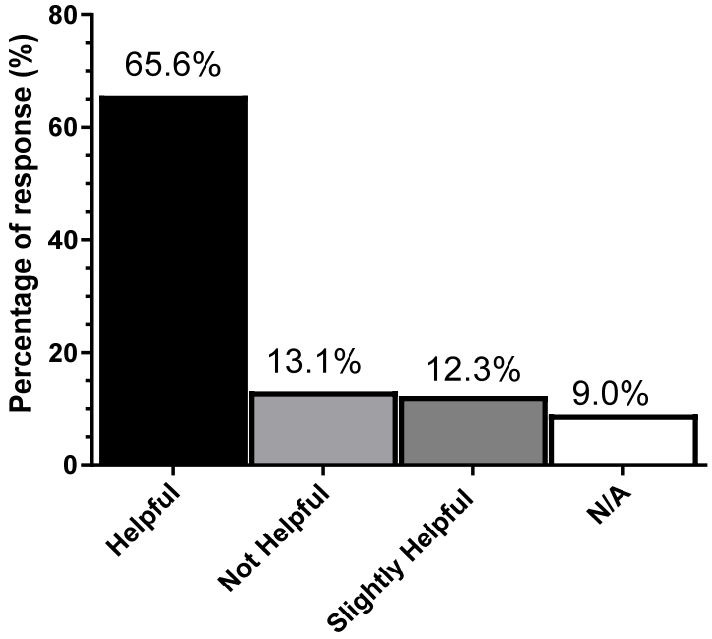

Figure 2. Student perspectives on the efficacy of virtual lab simulations and YouTube videos in comprehending microbiology lab etiquette.

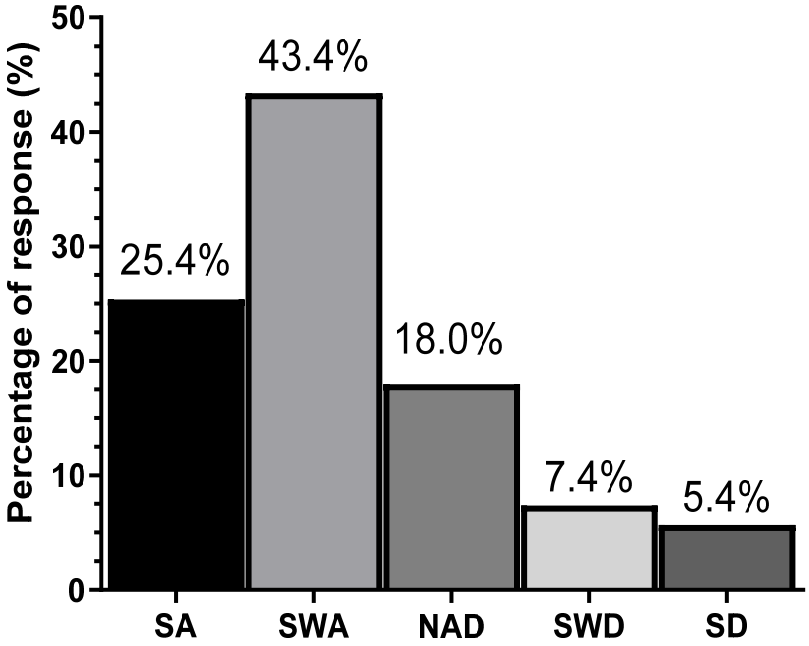

Figure 3. Student viewpoints regarding their enjoyment of virtual lab simulations. Response categories include SA (Strongly Agree), SWA (Somewhat Agree), NAD (Neither Agree nor Disagree), SWD (Somewhat Disagree), and SD (Strongly Disagree).

Furthermore, students were assessed on whether YouTube videos aided in identifying lab apparatus, with responses recorded on a Likert scale for the statement "YouTube videos helped to identify lab apparatus". Results showed that 23.8% strongly agreed, 23.6% somewhat agreed, and 17% neither agreed nor disagreed with the usefulness of videos in identifying lab apparatus. However, 5.7% somewhat disagreed and 4.9% strongly disagreed (Figure 4).

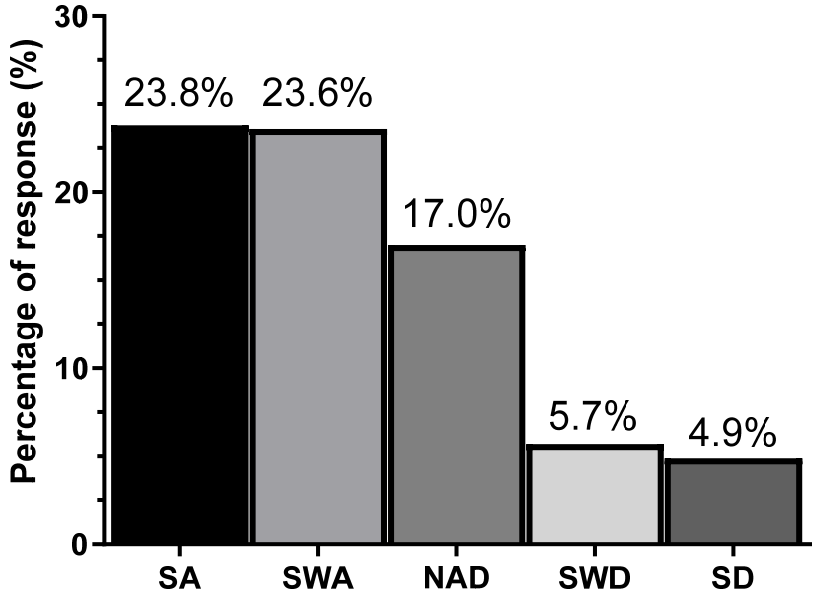

Figure 4. Student viewpoints regarding the utility of YouTube videos for recognizing laboratory equipment. Response categories include SA (Strongly Agree), SWA (Somewhat Agree), NAD (Neither Agree nor Disagree), SWD (Somewhat Disagree), and SD (Strongly Disagree).

Lastly, students' perceptions regarding the helpfulness of virtual lab simulations in understanding lecture concepts were explored. Using a Likert scale for the statement "Virtual lab simulations helped with the understanding of lecture concepts", 32.2% strongly agreed, 35.5% somewhat agreed, and 15.7% neither agreed nor disagreed. Conversely, 9.9% somewhat disagreed and 6.6% strongly disagreed with the statement (Figure 5).

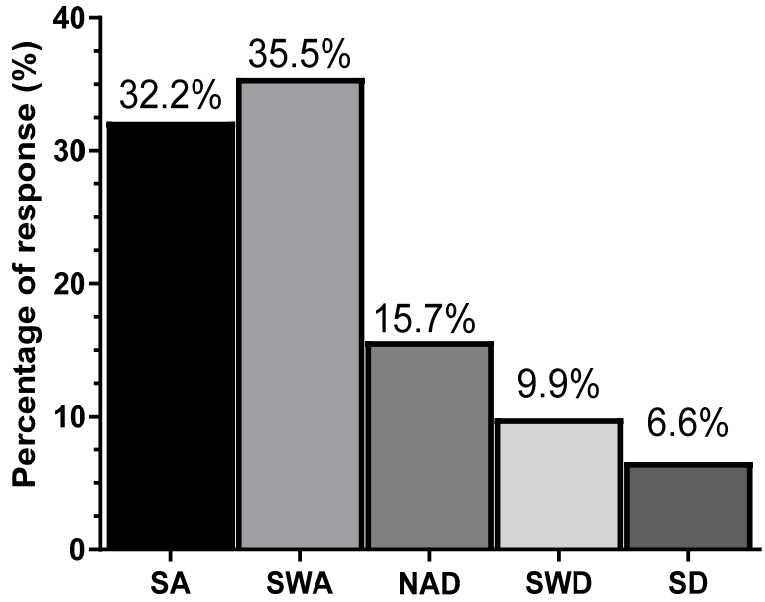

Figure 5. Student viewpoints regarding the efficacy of virtual lab simulations in enhancing the comprehension of lecture concepts. Response categories include SA (Strongly Agree), SWA (Somewhat Agree), NAD (Neither Agree nor Disagree), SWD (Somewhat Disagree), and SD (Strongly Disagree).

4. Discussion

The global upheaval caused by the COVID-19 pandemic significantly impacted education, affecting approximately 1.6 billion students [20]. In response to this unprecedented challenge, numerous countries, including the USA, hastily implemented various forms

of remote learning as an emergency measure [21]. North Carolina A&T State University, recognizing the need for adaptability, incorporated remote learning extensively for biology courses during the pandemic. This study aims to examine the advantages and disadvantages of employing videos and virtual lab simulations while delving into student perceptions within a university microbiology lab course, comparing it to the traditional in-person lab format. The findings revealed a preference among most students (57.2%) for hybrid learning, with an acknowledgment that lab simulations and videos were instrumental in comprehending microbiology lab practices. Recognizing the pivotal role of technology in effective teaching, our study aligns with the broader sentiment that students harbor positive attitudes toward virtual learning and the utilization of YouTube videos [22].

The integration of virtual labs and eLearning tools empowers students to conduct experiments unbound by temporal or spatial constraints. This flexibility proves advantageous, particularly for online students juggling work and family commitments. Our study corroborates the observations made by Burton [23], highlighting the increasing popularity of YouTube as an invaluable tool in online studies, enhancing students' preparedness and skill acquisition. Learning through YouTube is not only accessible and exciting but also offers the benefit of unlimited session repetitions and easily comprehensible explanations [24]. Moreover, students' proclivity towards engaging with dynamic activities, such as watching YouTube videos, rather than conventional textbooks and notes, is evident.

Video-based learning has emerged as a pivotal component in higher education, gaining even greater prominence amidst the challenges posed by the recent COVID-19 pandemic [11, 25,26]. Introducing video learning into lab-based teaching proves invaluable for elucidating complex biological phenomena, enhancing student engagement, and fostering a deeper understanding [27–29]. Additionally, video-based learning can accommodate a relatively large number of students and increase classroom utilization. In our study, students attested to the utility of videos in identifying lab apparatuses, with 47.4% expressing significant agreement. A parallel investigation in a Reaction Equilibria and Thermodynamics class echoed the potential of video-based learning in aiding students' comprehension of lab equipment [30]. Traditional approaches often involve memorization of apparatus lists with images and labels, but our study suggests that animations in videos or simulations provide a more effective alternative. Furthermore, virtual lab simulations afford students the opportunity to experiment without physical constraints, testing multiple scenarios and determining efficacy without real-world risks, whereas professors and students alike run the risk of breaking lab equipment and/or injuring themselves or others with in-person lessons. Video-based labs can still show every student how equipment can be used properly, setting them up for safety and success when and if they ever find themselves in a more traditional lab setting. Finally, video-based labs can provide a low-stakes environment in which students can run a digital device or equipment many times to understand the work or obtain the desired result. Each student will have the opportunity to manipulate variables, run the device, and immediately see the results. With each run, students engage more deeply with the concept, which is helpful for struggling students or those who need to repeat activities for improved comprehension. Video-based labs may also help students to deeply engage with course materials and future face-to-face lab activities. Despite the advantages offered by video-based labs, students may not feel confident applying what they have learned in a real-world scenario, especially if they are in a lab where they must use the same pieces of equipment or devices. This has an important implication for their performance and achievement in a higher institution of learning and on their career path.

Notably, a majority of students (68.8%) expressed enjoyment in utilizing virtual lab simulations, attesting to their efficacy in increasing interest, motivation, and overall learning effectiveness—a sentiment consistent with previous research [12]. Virtual labs play a dual role, fostering the development of students' laboratory skills while serving as a crucial tool for unhindered comprehension of class lectures. Engaging in virtual labs collectively in a classroom setting offers a more interactive platform for collaborative problem-solving compared to traditional lectures. Our investigation delved into whether

virtual laboratory experiments contribute to a better understanding of lectures, with a majority of respondents affirming that these experiments facilitated a direct conceptual grasp of the material. These findings align with prior research, highlighting the reinforcing impact of innovative technology-integrated teaching on students' reading comprehension and foundational understanding of key concepts [31,32]. Additionally, virtual labs provide students with opportunities to gain in-depth knowledge of lecture materials, offering a wide array of benefits in achieving desired learning outcomes. Moreover, virtual labs contribute to increased motivation in coursework and facilitate the overall science learning process [32]. It is important to highlight that virtual labs can help students assess complex concepts and associate them with real-life scenarios. These online activities can invigorate students to draw hypotheses and corroborate these through rich, interactive experiments. However, simulations may not always completely recreate real-life situations, and some can be costly and require constant software updates and maintenance.

With a surge in new cases, the COVID-19 pandemic kept many students at North Carolina A&T State University out of their classrooms. Results from this study illustrated that the students taking the General Microbiology course with a lab perceived virtual labs as beneficial. Although most of the students preferred the virtual platform, there were still a plethora of students who preferred a hybrid teaching style, that is, a combination of virtual and face-to-face labs to be used simultaneously. These findings will aid in the overall teaching of microbiology lab curriculum in the future. Based on the high percentage of students who indicated that they were content with a virtual lab, we would recommend its use in the future.

Strengths and Limitations

This study has some strengths and limitations that should be acknowledged. To the best of our knowledge, this study is the first to evaluate the perceptions and attitudes towards virtual labs in a general microbiology lab course at a historically black university during the first wave of the COVID-19 pandemic. Additionally, this is the first study to explore the advantages and drawbacks associated with the integration of videos and virtual simulations in a university microbiology lab course and compare them to the traditional in-person approach. An important strength of this survey is that the students selected were from four different microbiology laboratory sections from North Carolina A&T. The online survey provided a unique opportunity to reach out to all the respondents during the COVID-19 pandemic. Among the strengths, the online survey was cost-effective and reduced research costs. This provided a large amount of more honest and unambiguous responses. Furthermore, the survey collected and analyzed information regarding several important microbiology lab learning techniques, namely, face-to-face learning microbiology lab technique performance, watching YouTube videos of microbiology lab techniques, and performing lab simulations.

However, this study has potential limitations. First, students received extra credit for their participation in the study, which influenced their decision to complete the survey. Secondly, we could have used the program (atlas.ti 22) for all of the questions that required responses so students' responses could be thoroughly examined. This would be important because students' perceptions might change as the semester continues. Atlas.ti 22 is a coding program that assists with qualitative data by assigning "codes" to a data segment. These codes allow the user to assign specific codes to the responses that the students submitted. Finally, we could have also asked more questions about whether the students had taken a virtual or face-to-face class to filter out responses.

5. Conclusions

In summary, traditional, hands-on experiments in biological science labs are generally considered a hallmark of both undergraduate and graduate studies in most institutions. However, the COVID-19 pandemic necessitated the closure of physical campuses, prompting a swift transition to online instruction in higher learning institutions. This study

explores the incorporation of videos and virtual simulations in college microbiology lab courses, focusing on student perception and pros and cons. Our findings indicate a generally positive reception among students for videos and virtual simulations, attributing their efficacy to aiding comprehension of microbiology lab etiquette and lecture concepts. Notably, this marks the first exploration within the microbiology lab course domain to reveal students' predominantly positive attitudes toward online learning during the COVID-19 pandemic. However, video and virtual lab simulations may have some drawbacks, such as a lack of holistic and compelling learning experiences, which may not be a good substitute for complex and sophisticated lab activities. The implications of this study extend to university management and educators, offering valuable insights into student needs and perceptions. Such understanding facilitates strategic planning and the successful adoption of sustainable measures to navigate and implement evolving educational scenarios.

COVID-19 will always remain fresh in the minds of university stakeholders. More outbreaks of contagious respiratory diseases are inevitable. Educational institutions should reflect on the successes and failures of online learning during COVID-19 to come up with plans that include various tools for online lab sessions. Virtual microbiology labs can provide similar effects on students' knowledge, skills, theoretical concepts, hypothesis development and testing, and data collection and analysis to in-person labs [32]. However, virtual microbiology lab tools cannot completely replace the traditional microbiology lab experience of microbiology students [32]. Moreover, virtual microbiology labs can be used to prepare students for in-person microbiology labs. The findings from this study will undoubtedly help professors reflect on activities that enhance student engagement and create rich online learning environments at universities and colleges. For future studies, we intend to include the students' ages to assess if age has any influence on whether they enjoyed virtual labs or face-to-face instruction. Furthermore, we will implement two separate surveys, one at the beginning of the semester and one at the end of the semester, to investigate if the students' feelings changed with regards to face-to-face versus online/virtual lab formats.

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Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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