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Flipped laboratory classes: Student performance and perceptions in undergraduate food science and technology

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Abstract

In STEM (science, technology, engineering, and mathematics) courses, undergraduate laboratory classes are vital for students to develop competencies such as critical observation, collaboration, critical thinking, technical, and problem-solving skills. Thus, for students to successfully acquire these competencies, preparation for laboratory classes is essential. This study aimed to explore the students' performance and perceptions of online pre-laboratory videos and quizzes in undergraduate food science and technology. Quantitative data on student usage statistics of the videos, student performance in online quizzes and practical reports scores and student perceptions were analysed to provide a detailed perspective of the course. The students' performance was above 60% in all pre-lab quizzes for both the 2018 and 2019 cohorts. The average pre-lab video views were higher in the 2019 cohorts compared to the 2018 cohort. The majority of the students felt that the topics were well explained in the videos ($M = 4.25 \pm 0.84$) and it was easy to learn from the videos ($M = 4.31 \pm 0.76$). In terms of students perceptions, a strong positive correlations were found between course organisation and motivation and self-efficacy ($r = 0.86$, $p < 0.05$); course engagement and motivation and self-efficacy ($r = 0.82$, $p < 0.05$). The strongest positive correlation was between course organisation and online engagement ($r = 0.95$, $p < 0.05$). The results of this study suggest that the introduction of multimodal/digital preparation resources (pre-lab videos and online quizzes) was positively received and benefited the students. Students have engaged enthusiastically with these resources and completed the majority of the tasks set. These findings will further expand research directed towards student perception of the lab experience and aid in the adaptation of food science and technology curriculums to accommodate both student and university needs.

KEYWORDS

Flipped laboratory classroom, food science education, online pedagogy, online quizzes, pre-laboratory classes, YouTube videos

1 | INTRODUCTION

As consumer demand for healthy and convenient food products increases, so does the food industry's need for a large number of well-trained professionals to produce healthier food products, enhance manufacturing processes and ensure food safety and security (Floros et al., 2010). In order for food science and technology graduates to effectively address these needs, they must possess good laboratory competencies, be able to solve problems, think critically and apply acquired knowledge. Undergraduate food science and technology courses often use expository or confirmatory practical laboratories in which the research questions and procedures are already established (Crandall et al., 2015; Haagsman et al., 2020; Iwaoka, 2011). Expository laboratory practicals are commonly recognized as providing students with opportunities and competencies to learn practical-hands-on skills, interpret data, reinforce theoretical concepts, draw conclusions and stimulate interest in the subject matter. It is vital to have students develop and practice these skills, especially with today's 4th industrial revolution or industry 4.0 which is characterized by automation and big data.

As articulated by Gregory and Di Trapani (2012) "For any long-term benefit to be derived from practical laboratory classes, students' ability to be adequately prepared both conceptually and procedurally is essential". A common problem with undergraduate laboratory work is the lack of student preparation for laboratory classes (Shelby & Fralish, 2021). Undergraduate students rarely read from textbooks or laboratory instructions prior to arriving in the lab, even though the success of laboratory activities is dependent on the quality of pre-laboratory preparation (Altowaiji et al., 2021; Haagsman et al., 2020; Kong et al., 2020). This is manifested in the type of questions students ask during the laboratory session and failure to complete the required tasks. The laboratory manual, direct guidance, unfamiliar equipment and materials, technical expertise, theoretical background and time management have all also been established as possible causes of cognitive dissonance (Gregory & Di Trapani, 2012; Yeung & Schmid, 2005). As a result, undergraduate students often experience cognitive overload in laboratory classes, decreasing the likelihood of achieving the desired learning outcomes (Jolley et al., 2016). This problem can further be exacerbated in large classes with fewer resources such as unit operations (e.g., having one colloid mill). Furthermore, students typically spend more time on post-laboratory exercises, which can take up to Five hours per activity, than on pre-laboratory preparations. These tasks mostly consist of writing reports, which are typically completed or partially completed outside of the laboratory.

The flipped classroom (FC) approach/model has been reported to facilitate the reduction of the amount of new information students are exposed to when they enter the laboratory (Mellefont & Fei, 2016). The FC is a form of Blended Learning (BL), that reorganizes the time in and outside the classroom. In the FC model, students are exposed to initial learning material prior to face-to-face class through a variety of methods, many of which are technology-based or technology-enhanced and learner-controlled, such as instructor-provided videos (Long et al., 2016; Thai et al., 2017). When carefully designed, organized and well-executed, flipped laboratory classrooms (FLC) can result in better learning outcomes than traditional lectures due to independent learning and critical thinking. The FC falls within the ambit of constructivism learning theory since it facilitates the active engagement of students with the curriculum in a variety of ways. Research indicates that FC helps students learn at their own pace, space, take control and responsibility for their learning (Mellefont & Fei, 2016), encourages students to actively engage with lecture materials (le Roux & Nagel, 2018), spend more time in preparatory work, and get more involved during classroom activities (Flores et al., 2016; Nouri, 2016).

Traditional pre-laboratory exercises where students are expected to read the laboratory manual, complete a paper-based quiz or passively listen to a short lecture before the beginning of the laboratory session are common in many universities. Recently there has been a paradigm shift towards pre-laboratory exercises which incorporate various multimedia such as videos and online quizzes given the prominence of technology as a pedagogical tool (Altowaiji et al., 2021; Haagsman et al., 2020; Nadelson et al., 2015; Stieff et al., 2018). Pre-laboratory material (videos) can be used to facilitate students engagement and encourage thorough planning. Pogačnik and Cigić (2006) found that by completing more of their exercises before entering the laboratory, students were able to lower their post-lab workload in undergraduate chemistry. In a study conducted by Donovan and Lee (2015), the FC model was applied in a semester-long group project for undergraduate students enrolled in sensory evaluation of foods course. The findings showed that the flipped laboratory accurately mirrored lecture content, allowed for the completion of the majority of group projects in the classroom and improved student learning by integrating lecture knowledge with hands (2016) used pre-lab video demonstration and online quizzes in a large second-year undergraduate analytical chemistry class and reported a positive effect on students perceived learning and this was attributed to higher levels of preparation.

Moreover, video clips combined with self-assessment methods were reported to be effective pedagogical tools for improving learning outcomes and student success rates in mechanical engineering laboratories (De-la Flor López et al., 2016). Chittleborough et al., and Treagust (2007) investigated the effectiveness of online pre-lab activities (quizzes) in a chemistry lab course for nonmajors. The students felt more prepared for the lab after completing the online tasks than when reading the lab instructions before the lab sessions. Several studies report that students enjoy the laboratory sessions and can learn at their own pace and that they prefer the flipped classroom over traditional approaches (Chittleborough et al., 2007; Mutch-Jones et al., 2021; Whittle & Bickerdike, 2015). Online pre-lab quizzes have the added benefit of providing real-time formative feedback to students prior to the laboratory sessions. For economically disadvantaged students, access to technology to view videos or complete online quizzes can be a challenge. Video quality can be low, causing students to misunderstand the material and be unprepared for learning activities.

Despite evidence suggesting the potential benefits of the flipped laboratory classroom and pre-laboratory exercises, no studies have been reported on the use of pre-laboratory exercises in undergraduate food science and technology. Moreover, little is known about the students' performance and perceptions of pre-laboratory exercises in food science and technology courses where students are required to integrate theory and practice and grasp complex scientific concepts. Therefore, this study sought to evaluate the students' use of preparation resources and to determine students' performance and perceptions of pre-laboratory classes facilitated through a flipped classroom model.

2 | MATERIALS AND METHODS

2.1 | Institutional context

Food technology 1 (FOT150S) is a year-course (two semesters) offered at a University of Technology (UoT), South Africa. FOT150S is a compulsory course for all students registered for a Diploma in Food Science and Technology and comprises both theory and practical components. First-year students enrolled for the course in 2018 ($n = 83$) and 2019 ($n = 106$) were exposed to pre-laboratory exercises. Over 2 years, the course set-up and activities remained the same. Participants were requested to sign an informed consent containing information on the research and data collection. Participants were informed that their grades for the course would not be impacted by their participation, or lack thereof, in the survey. The study received ethical clearance from the University's Centre for Higher Education Development ethics committee (FREC:REF: 11/2018).

2.2 | Development of online pre-laboratory resources

Illustrative teaching videos were developed for each practical session which represents the fundamental aspects (e.g., overall objectives of the practical, operation of equipment, food safety and hygiene aspects, etc.). Selected YouTube videos links and descriptions are provided in supplementary material 1 as examples. The videos are intended to help students prepare for the laboratory session and also serve as a useful reminder of the theoretical aspects covered in face-to-face classes earlier in the course. A total of 12 videos, covering five distinct practicals were developed and published as unlisted content on YouTube and then shared by embedding the links in the blackboard learning management system (LMS). The video links were activated a week before the corresponding laboratory session with the view to provide students with ample time to prepare and familiarize themselves with the practical content. The duration of the designed videos was between approximately 7 and 21 min depending on the topic.

2.3 | Pre-practical tests

Before attending a laboratory session, students were required to complete an online test (quiz) on LMS. A pool of test questions comprising of various question types (multiple-choice, multiple answers, calculated, fill in the blank, matching and ordering, etc.) were designed for each laboratory practical and when deployed, the questions were randomized. Students were given two attempts, however, the second attempt involved different questions of the same theme than those used in the first attempt. The highest score for both attempts was taken as the final mark. An example of pre-laboratory online test (quiz) questions and answers are provided in supplementary materials 2 and 3. The online tests were designed to assess the understanding of the theory underpinning the practical/experiment, practical details (how to calibrate a pH meter), food safety and hygiene considerations and interpretation of results (color change in blanched vegetables). Negative marking was used to discourage the students from selecting all options or guessing in multiple answer questions. After the practical session, students were required to submit a formal practical report online. These formal reports include an introduction, materials and methods, results and discussion and a conclusion section. The reports were graded using an online rubric developed by the authors. The rubric was used to score each component of the lab report and each section in the rubric had specific details about each component and the lab experience.

TABLE 1 Cronbach's alpha for the identified constructs

Constructs	No of items	Cronbach's α
Effectiveness of videos	6	.804
Online feedback	3	.808
Motivation and self-efficacy	3	.770
Organisation	3	.851
Online engagement	4	.786
Online active learning	8	.864

2.4 | Data collection and analysis

Three types of data were collected, online pre-lab and laboratory report scores (performance), usage statics of the videos and an online survey (students' perceptions). The number of hits each unlisted video received was captured from both cohorts from the YouTube website. Only students registered for FOT150S had access to the links via the LMS. Students' perceptions of the online pre-lab component (implemented pedagogy) were collected at the end of the 2018 and 2019 academic years, respectively. In both instances, students anonymously completed a questionnaire on the LMS. The survey contained demographic questions, including the type of devices students used to access the online content. Students also responded to closed questions using a 5-point Likert scale (1: strongly disagree; 5: strongly agree). The scale adapted from Coates (2007) was modified and divided into six dimensions: effectiveness of videos, online feedback, motivation and self-efficacy, course organization, online engagement and online active learning. All data were tabulated and means (M) and standard deviations (SD) were calculated for each cohort for each variable. Student's t-tests (two-tailed) were used to determine any statistically significant differences in module performance (pre-practical quiz and laboratory reports) between the two cohorts (2018 and 2019). All quantitative data were analyzed using SPSS 27.0 (2005) (SPSS Inc., Chicago, IL, USA). Cronbach alpha was used to verify the coefficient of reliability of the survey questions. In a study reported by Khan et al., and Tahir (2021), it is posited that an instrument is regarded as reliable if the Cronbach alpha coefficient is greater than 0.5. The reliability value of Cronbach's alpha between ± 0.41 and ± 0.70 qualifies for moderate reliability of the scale measured, while a greater value than ± 0.70 shows high internal consistency. As exhibited in Table 1, all constructs evaluated in this study showed Cronbach values greater than 0.70, significantly higher than the threshold value of 0.5. This means that all constructs have a high degree of internal consistency with their measurement indications.

3 | RESULTS AND DISCUSSION

3.1 | Student demographics and online access

All participants for the respective cohorts (2018 and 2019) were first-year undergraduate students enrolled for the diploma in food science and technology. The age and gender of the participants are displayed in Figure 1 (a) and (b) and reflects a dominance of the 19 years old and younger generation. The age distribution 30 and above years was the least in both 2018 and 2019 cohorts, respectively. The majority of the students were under the age of 19 and these can be categorized as digital natives or tech-savvy students (Olivier, 2016). As can be seen from Figure 1 (c) and (d), it is notable that most students reported having a relatively fast and consistent internet connection in both cohorts (2018 and 2019) and accessed the LMS through desktop computers provided on campus (37–42%) followed by the use of smartphones (21–25%) and personal laptops (20–24%). The high usage of desktop computers on campus is not surprising, since the university provides a secure internet connection for all students. Results also indicate that 21 and 25% of the students use mobile devices for their learning for the 2018 and 2019 cohorts, respectively. These results indicate that majority of the tech-savvy students can access teaching and learning content using their digital gadgets for learning (Mshayisa, 2020; Olivier, 2016). In higher education, digital technologies are seen as transformative tools for teaching and learning. Results obtained from this study indicate that there is uptake and use of digital technologies by students in food science and technology. Thus instructors need to innovate their teaching practices and incorporate digital technologies to enhance students learning experiences in laboratory classes especially considering the impact of the 4th industrial revolution on education.

3.2 | Student preparation for the labs

Participants were asked how much time they spent preparing for the laboratory sessions. A comparison of the responses for the two respective cohorts is shown in Figure 2. In the 2018 cohort, 45% of the students reported spending between 15 and 30 min on average preparing for the practical sessions compared to 23% in 2019 (Figure 2a). Interestingly 73% of the 2019 cohort reported having spent more than 30 min in preparation for the practicals compared to 40% reported by the 2018 cohort. This implies that the students in the 2019 cohort spent more time preparing for the laboratory sessions. This self-reported 30–45 min range falls within the 30–60 min range reported

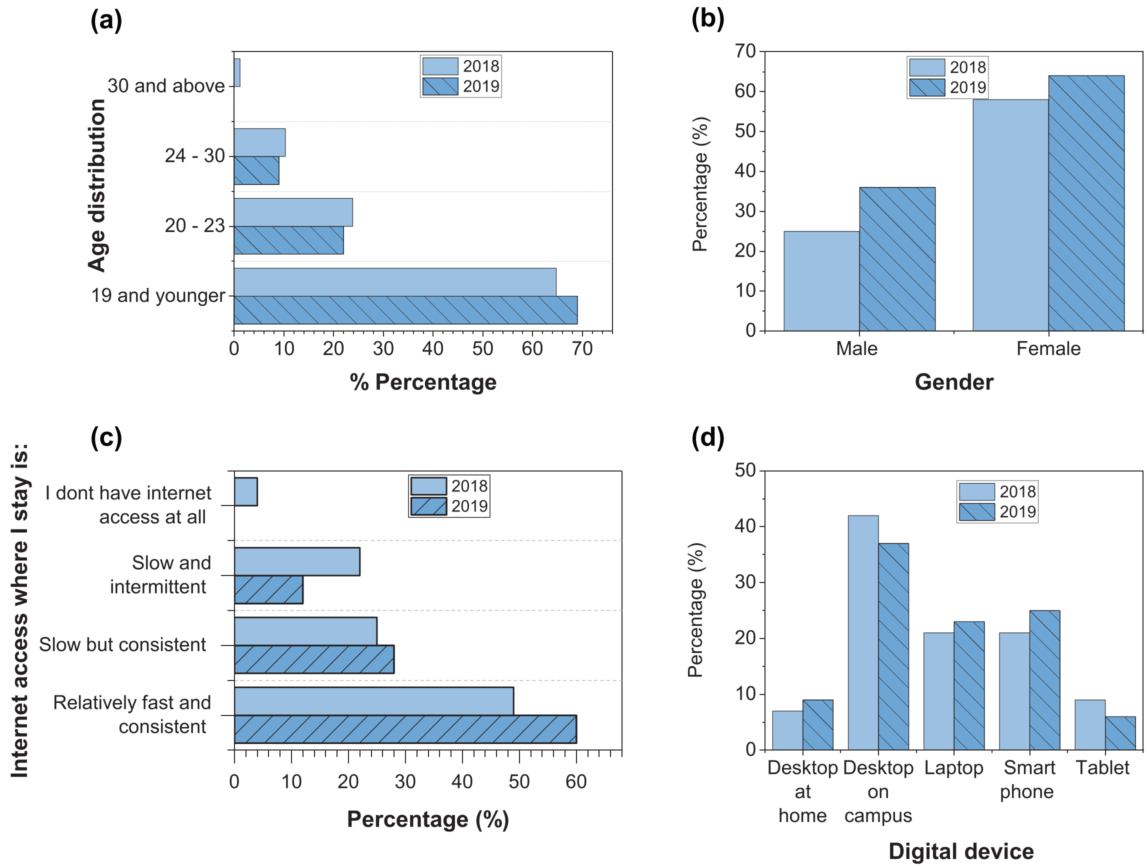

FIGURE 1 Student demographics data for the 2018 and 2019 cohorts. (a) Age distribution (b) gender (c) Internet access and (d) Access to digital devices

by Gregory and Di Trapani (2012). Potential reasons for this may be that the students found the pre-laboratory activities useful and engaged with them enthusiastically as pedagogical tools. The findings of Jolley et al. (2016) who noted that students enthusiastically embraced optional online pre-laboratory exercises in analytical chemistry aligns well with the results obtained in this study. Additionally, the data analytics of YouTube videos where there was a high average watch time (Table 2) confirm that students used the pre-laboratory videos designed by the instructor and thus this study adds to the existing body of knowledge on the use of digital resources for undergraduate laboratory preparation, more importantly in the context of food science and technology.

Participants were also asked in terms of their perceived preparedness for the laboratory sessions. In the 2018 cohort, 18% of students reported not being well prepared and 10% not prepared at all. While in both 2018 and 2019, 52 and 84% of students reported being somewhat or very prepared, respectively (Figure 2b). This suggests that the nature of the preparatory material developed by the authors compelled the students to come prepared in the sessions. However, in the 2019 cohort, there was a small number of students whose perceived preparedness and time spent in preparing for the laboratory session was poor (<10%). Individual students may appreciate the visual aspect of the videos to differing degrees based on their learning styles. However, taken collectively, the results of this study demonstrate that when carefully designed, the provision of pre-laboratory resources compels the students to prepare for the laboratory sessions and thereby they feel prepared.

3.3 | Pre-lab videos

Pre-laboratory videos and online quizzes, all of which were incorporated in the Blackboard LMS, were used to modify the laboratory structure from a didactic to a student-centered learning approach using the flipped classroom model. The aim of creating and distributing videos to students was to aid them in becoming more self-sufficient in the laboratory/pilot plant. The YouTube video analytics (Table 2) reveals that there were more views than students enrolled in the module indicating that videos were viewed more than once. The pH evaluation of different food items

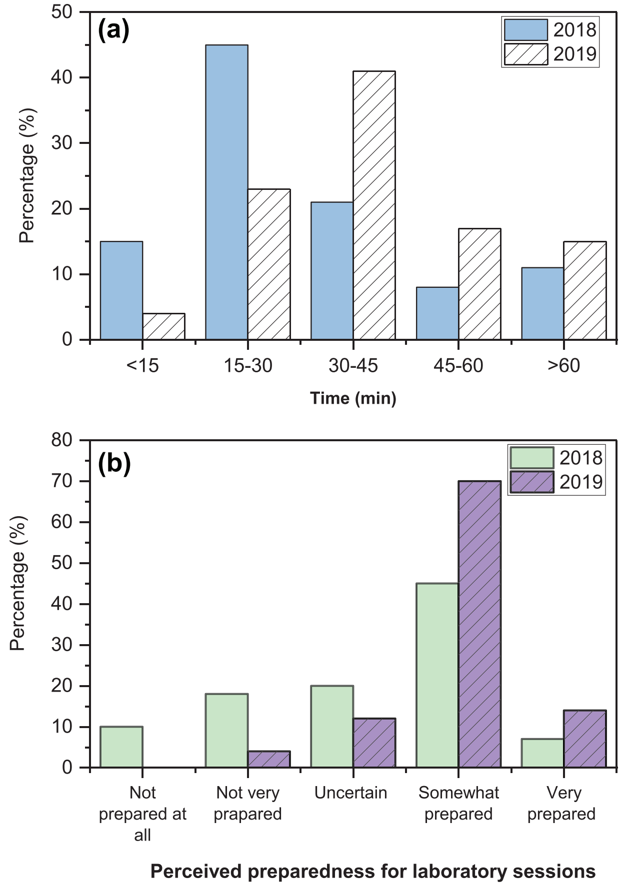

FIGURE 2 Student preparedness (a) Average preparation time for laboratory classes (b) Perceived preparedness for the laboratory session

video had the longest total view time in both 2018 and 2019 cohorts, 310 and 277 views, respectively. The number of views and average view duration indicate that certain students viewed the videos multiple times. In addition, the more technologically aware students would have understood how to download videos to watch later on their own time. In general, an increase in viewing time was observed in the 2019 cohort. The increase in average viewing time in the 2019 cohort, who had more views refutes the possibility of a transient novelty effect in the FC approach to pre-laboratory classes in undergraduate food science and technology. The results of this study are in line with the findings of Spagnoli et al. (2017) who also reported a high number of views on the instructional YouTube videos before the online pre-lab quiz submission. To the best of our knowledge, this is the first study to investigate the students use of pre-laboratory videos in undergraduate food science and technology and therefore has strong implications for addressing the long-standing challenge of poor laboratory preparation for laboratory classes.

3.4 | Student performance in online prelabs

To examine the possible difference in student performance between the two cohorts, an independent t-test was conducted on all five online pre-lab quiz scores (Table 3). Since not all students completed the online pre-labs, the N (number of participants) is smaller for some items. From the results in Table 3, the highest performance (M = 96.54 ± 13.43) was recorded in the first practical (Pearson square) and the lowest (M = 61.16 ± 13.07) was on the Blanching practical. When an independent t-test (two-tailed) was conducted to compare the student performance in an online pre-lab for the blanching practical. There was no significant difference ($p > 0.05$) in the marks for the 2018 (M = 65.48, SD = 15.47) and 2019 (M = 61.16, SD = 23.07)

TABLE 2 FOT150S video analytics based on results obtained from YouTube website

Video (Topic)	Duration (min)	YouTube views 2018 ($n = 86$)	2019 ($n = 106$)	YouTube time watched (h) 2018 ($n = 86$)	2019 ($n = 106$)
1. Hygiene and handwashing protocol	04:41	191	159	17.10	14.20
2. Calculation of sugar and salt concentrations using Pearson square	11:24	277	176	22.90	19.00
3. pH evaluation in various food products	14:41	277	310	36.80	44.80
4. Size reduction and blanching efficacy of fruits and vegetables	11:01	174	139	25.50	19.50
5. Sunflower seed oil extraction and centrifugation	15:41	234	323	31.30	43.80
6. Peanut roasting and peanut butter manufacturing	14:53	115	125	21.80	28.50
7. Manufacturing butter and mayonnaise	13:56	116	129	15.90	18.10

TABLE 3 Independent t-test results of online pre-lab quizzes between the 2018 and 2019 cohorts

Online pre-practical tests	Year	*N*	Mean	Std. deviation	Std. error mean	t	*p*-value Sig. (2-tailed)
Pre-practical - Pearson square method	2018	83	96.54	13.43	1.47	0.563	0.574
	2019	106	95.25	17.07	1.64		
Pre-practical - Evaluation of pH in various foods	2018	83	87.23	22.40	2.46	0.294	0.769
	2019	101	86.34	18.72	1.86		
Pre practical - Blanching	2018	83	65.48	15.47	1.70	1.523	0.130
	2019	103	61.16	23.07	2.27		
Pre-practical - Peanut butter processing	2018	80	82.85	18.80	2.10	−1.917	0.058
	2019	106	87.44	11.82	1.15		
Pre-practical - Emulsions	2018	83	61.63	14.30	1.57	−10.833	0.000
	2019	97	84.61	14.08	1.43		

TABLE 4 Independent t-test results of practical reports between the 2018 and 2019 cohorts

Practical reports	Year	*N*	Mean	Std. Deviation	Std. Error Mean	t	Sig. (2-tailed)
Practical report - Pearson square method	2018	83	55.99	6.20	0.68	−0.847	0.399
	2019	77	57.72	16.93	1.93		
Practical report - Evaluation of pH in foods	2018	83	60.02	13.27	1.46	1.714	0.088
	2019	106	56.93	11.51	1.12		
Practical report - Blanching practical	2018	83	47.46	12.89	1.42	−7.202	0.000
	2019	105	67.41	24.40	2.38		
Practical report - Peanut Butter practical	2018	83	49.04	15.10	1.66	−11.998	0.000
	2019	104	77.25	16.80	1.62		
Practical report - Emulsions	2018	79	78.73	14.62	1.65	2.711	0.007
	2019	104	71.75	20.50	1.98		

cohorts; t = 1.523, $p = 0.130$. There were no significant differences ($p > 0.05$) between the two cohorts on the Pearson square, evaluation of pH, in various foods peanut butter and blanching prelabs ($p = 0.574$; $p = 0.769$; $p = 0.130$; $p = 0.058$), respectively. In terms of the emulsion practical, the mean performance for the 2018 cohort was significantly higher ($p < 0.05$) compared to the 2019 cohort (Table 3). To further assess the effects of the curricular change, the practical reports scores for both cohorts were also evaluated for the same practicals. There were no significant differences ($p > 0.05$) in student practical report scores for the Pearson square and pH evaluation practical reports ($p = 0.399$ and $p = 0.088$) respectively (Table 4). The 2019 cohort performed significantly ($p < 0.05$) better on the blanching and peanut butter practical reports compared to the 2018 cohort. These results suggest that the ability of students to achieve the learning outcomes was not hindered by the implementation of prelab activities (online videos and quizzes). Furthermore, evidence suggests that more efficient pre-laboratory preparation can enhance the ability of students to demonstrate desirable learning outcomes.

3.5 | Students perceptions

3.5.1 | Student perceptions of the video resource (VR) dimension

It is critical to understand and evaluate student opinions or perceptions of proposed teaching and learning

TABLE 5 Students perceptions of the measured constructs

Code	Statement	Mean ± SD
VR	I like viewing pre-practical videos better than reading text material	4.40 ± 0.67
VR	The pre-practical videos were helpful since I could watch them on my own time	4.43 ± 0.64
VR	It was easy to learn from the videos	4.31 ± 0.76
VR	The topics were well-explained in the videos	4.25 ± 0.84
VR	Video-lessons material was correctly designed, well-structured and clearly-defined	3.75 ± 1.06
VR	Video demonstrations of the methods to be used in the practical gave me a clear idea of what I was expected to do	4.05 ± 0.93
CF	Getting immediate feedback on the online pre-laboratory was valuable	4.12 ± 0.84
CF	The online pre-lab provided feedback on my understanding	4.23 ± 0.75
CF	Having multiple attempts on the quiz allowed me to correct my mistakes	4.52 ± 0.63
MSE	The videos and online pre-prac tests motivate me to study through the year	4.31 ± 0.83
MSE	Videos and online pre-pracs assist in my preparation for the labs	4.14 ± 0.81
MSE	I feel prepared for the laboratory practical classes	4.26 ± 0.78
CO	The structure and the layout of the preparation resources were clear and easy to understand	4.17 ± 0.75
CO	Helped me to develop my laboratory planning skills	4.26 ± 0.78
CO	Helped me to manage my time more efficiently during lab	4.10 ± 0.76
OE	I used Blackboard to improve how I learn in the module	4.16 ± 0.75
OE	Blackboard helped me to interact better with the module content	4.25 ± 0.78
OE	I used Blackboard to manage my studies in the module	4.09 ± 0.76
OE	Blackboard is a major part of Food Technology 1 (FOT150S)	4.13 ± 0.74
OAL	I used online materials on BB to improve my learning	3.75 ± 0.94
OAL	I used online materials on BB to make lectures more meaningful	4.20 ± 0.63
OAL	I identified expected work standards using BB	4.18 ± 0.88
OAL	I found that online materials on BB challenged me to learn	4.17 ± 0.76
OAL	I used online feedback to improve my understanding of a topic in Food Technology 1 (FOT150S)	4.12 ± 0.90
OAL	The lecturer provided constructive feedback following the completion of assessments	4.11 ± 0.87
OAL	An online blended learning approach helped to master the learning material at my own pace	3.79 ± 0.84
OAL	Online learning helped me with my time management	4.00 ± 0.77

A 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree was used for each quantitative question.
Abbreviations: VR, Video resources; CF, course feedback; MSE, motivation and self-efficacy; CO, course organization, OE, online engagement; OAL, Online active learning.

interventions or learning strategies before they are implemented on a broad scale. Therefore, in addition to student performance, this study sought to understand the student's perceptions of flipped laboratory classes where online videos and quizzes were used as preparation resources. A descriptive quantitative analysis was used to compare the means and standard deviation and the results are presented in Table 5. The students in this study agreed strongly that they like to view the pre-practical videos than reading text material (M = 4.40 ± 0.67). This statement had the highest mean among the six items evaluating the video resource dimension. The difference in learning styles (defined as visual, tactile, or auditory) should always be taken into cognizant when developing pedagogical practices for students. The majority of the students felt that the topics were well explained in the videos (M = 4.25 ± 0.84) and it was easy to learn from the videos (M = 4.31 ± 0.76). According to the students, the resources are simple to find and use and they assist them in comprehending both the theoretical background of the practical lesson and how the experiment will be conducted out in the laboratory. These results also suggested that this innovative approach fostered learning and provided positive learning experiences for the students from the food science and technology program in both cohorts. Moreover, participants expressed that the videos were helpful since they could watch them on their own time (M = 4.43 ± 0.64). This is the benefit of blended teaching pedagogy where learning is not constrained by space or time. The results of this study build upon the current literature on the use of videos to enhance students preparation for laboratory classes in STEM courses (Altowaiji et al., 2021; Donovan & Lee, 2015; Gregory & Di Trapani, 2012; Johnson et al., 2006; Jolley et al., 2016; Nadelson et al., 2015; Stieff et al., 2018). This finding has important implications for developing pre-laboratory videos to enhance student learning and preparation for laboratory classes.

3.5.2 | Student perceptions of the course feedback (CF) dimension

Course or instructor feedback is vital for any successful improvements to be derived in student learning. Results presented in Table 5 indicate that students received feedback on the online pre-practical quiz (M = 4.23 ± 0.75) and most students realize the benefits of formative feedback and were appreciative of the opportunity to correct their mistakes (M = 4.52 ± 0.63). This indicates that students are interested in learning and studying food science and technology and in appreciating the role of feedback in the process of learning. Moreover, if a tool is thoughtfully designed and mediated by the teacher, students are more likely to be highly motivated and satisfied to use it (Waha & Davis, 2014). The type and amount of feedback provided have an important role in learning skills such as problem-solving, analytical thinking and processing of food products in food science and technology and can help improve links between theory and practical work. When a student receives feedback on their progress, they are motivated to do better and gain confidence that they are "on the right track" with their thinking (Jolley et al., 2016). Moreover, according to Basitere et al. (2017), automated feedback was crucial to assist students to identify their misconceptions and work on improvements in a chemical engineering course.

3.5.3 | Student perceptions of the motivation and self-efficacy (MSE) dimension

One of the less discussed areas of blended pedagogy in Science, Technology, Engineering, and Mathematics (STEM) courses is the need for motivation and self-efficacy especially as it relates to the online component. As it can be seen in Table 5, providing the students with pre-lab videos motivated them to study (M = 4.31 ± 0.83) and remain engaged in the module while assisting them in their preparation for the laboratory (M = 4.14 ± 0.81). The results of this study are in agreement with Jolley et al. (2016) who reported that when pre-laboratory resources were made available, students in analytical chemistry reported reduced anxiety and were confident in their preparation for the laboratory classes. According to Bravo et al., and Fernandez (2011), students considered that videos are a more enjoyable way to introduce the subject and a means to increase their motivation. Moreover, the results reported are consistent with the findings of Hung et al., and Own (2010) that motivation may play an important role in online learning. The results of the motivation dimension reported in this study correlate with the observed access and usage statistics of the resource reported in section 6.1.

3.5.4 | Student perceptions of the course organization (CO) dimension

Blended and online courses are reviewed after they are deployed to measure the quality of the instruction as well as the preferences and attitudes of students regarding the use of technology to enhance their learning. Poorly designed online course components tend to discourage students and cause anxiety on the students. As re-iterated by Smyth et al. (2012), the ease of access and navigation of any Virtual Learning Environment (VLE) is crucial in the effectiveness of online education. The authors also measured the students' perception of the course organization. A very high proportion of the students reported that the structure and layout of the online preparation resources were clear and easy to understand (M = 4.17 ± 0.75) and such a structure aided them to develop laboratory planning skills (M = 4.26 ± 0.78) as shown in Table 5. A well-organized online course helps the students easily navigate the course and it is critical to help students prepare for their practicals session. Clear practical objectives, due dates and rubrics for practical reports were among the features of the online component of FOT150S to support effective course design.

3.5.5 | Student perceptions of the online engagement (OE) dimension

The ability to engage students outside of the classroom is an important part of today's teaching and learning practices. When students are given opportunities to learn at their own pace, space and time, engaged learning practices are most effective (Ranga, 2017). Pre-laboratory materials should, according to Jolley et al. (2016) promote students' participation and support good preparation. The LMS (Blackboard) plays a crucial role in facilitating

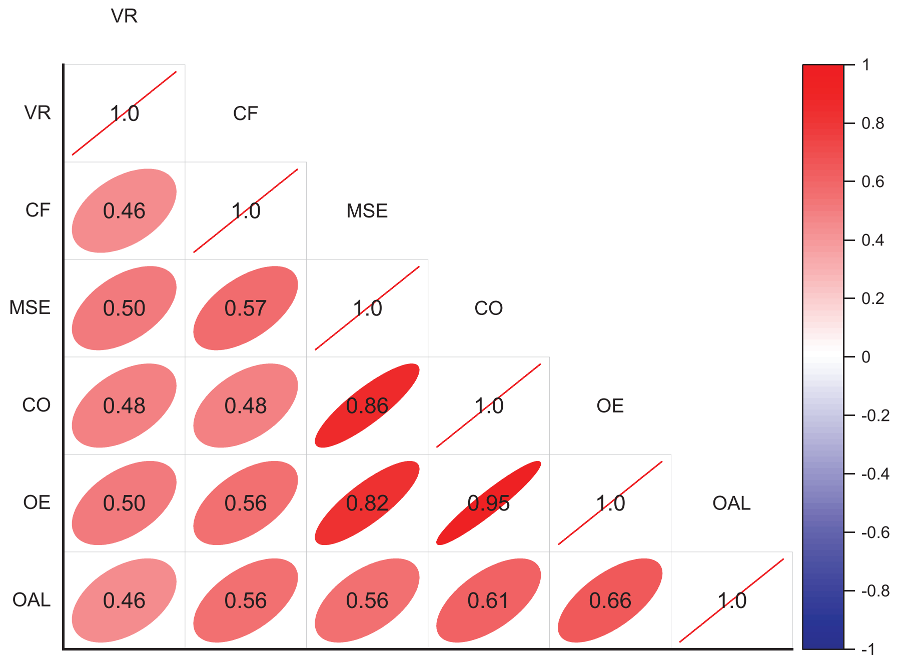

FIGURE 3 Spearman's correlations plots of student perceptions in FOT150S. The red color of the ellipse indicates positive and blue negative correlations between variables at $p < 0.05$.
Note: Video resources (VR), course feedback (CF), motivation and self-efficacy (MSE), course organisation (CO), online engagement (OE) and Online active learning (OAL)

student engagement and learning online. The students' perception results of online engagement in FOT150S are presented in Table 5. The students reported that the LMS helped them to interact with the content better (M = 4.16 ± 0.75) and improve their learning (M = 4.16 ± 0.75). The students viewed the LMS as an integral part of the course FOT150S (M = 4.13 ± 0.74). These results are in line with previous research which demonstrated that online prelab video models of instruction, in which students watch online videos of basic course topics before receiving face-to-face instruction, boost student engagement and learning results significantly (Deslauriers et al., 2011; Gregory & Di Trapani, 2012; Haagsman et al., 2020; Smerdel & Hajric, 2020). The results of this study further contribute to the earlier studies reported by Coates (2007) that students reporting an intense form of engagement are highly involved with their university studies.

3.5.6 | Student perceptions of the online active learning (OAL) dimension

Much of what we understand about student engagement in higher education stems from on-campus research. According to Coates (2007), engagement is a broad construct intended to encompass salient academic as well as certain non-academic aspects of the student experience. Radloff and Coates (2009) report that for students to be regarded as "engaged" there needs to be evidence that they are involved in "educationally purposeful activities". In this study, the creation of online pre-practical videos and quizzes was aimed at providing student-centered learning practices and reduce anxiety or cognitive overload during practical sessions. The LMS plays a critical role in facilitating online active learning. Students can spend more time in the lab honing their experimental abilities if they are provided with an overview of the experiment and the opportunity to engage with important background knowledge before the lab session. The students reported that they used the online materials to make their learning more meaningful (M = 4.20 ± .63) and improve their learning (M = 3.75 ± 0.94). These results support the notion that students who demonstrate generally higher perceptions of active learning practices online may be more engaged in an online course. Such results may support Cole et al. (2019) claim that some students may choose to "opt-in" to online courses. Indeed, it appears that FOT150S students view active learning practices as important generally, as well as in their specific course learning experiences.

3.5.7 | Relationships between measured variables

In order to study the potential relationship between the student's perceptions of the online pre-practical videos and the variables mentions previously, the correlation coefficients between these variables were calculated, the results of which are shown in Figure 3. Strong positive correlations were found between course organization and Motivation and self-efficacy (r = 0.86, $p < 0.05$); course engagement and Motivation and self-efficacy (r = 0.82, $p < 0.05$). The strongest positive correlation was between course organization and online engagement (r = 0.95, $p < 0.05$). It should be noted that student motivation and self-efficacy was positively and significantly correlated with course organization. Thus, the more well organized the inline course resources were, the more motivated the students to complete the online pre-practical tasks (watching videos and completing the quizzes), and vice versa. Interestingly, there was a moderate correlation between video resources and online active learning (r = 0.46, $p < 0.05$). Taken collectively, the results presented in this paper indicate the appropriateness of designing and providing pre-laboratory videos and online quizzes in the context of food science education and support a greater reliance on these pedagogical tools to engage students and improve their learning experiences. Most notably, this is the first study to our knowledge to investigate students perceptions and performance of pre-laboratory classes facilitated through a flipped classroom model in two respective cohorts in food science and technology curricular. Thus the findings of this study have significance in the design of food science curricular and the training of students in this field.

4 | CONCLUSION

The results of this study suggest that the introduction of preparation resources (pre-lab videos and online quizzes) was positively received and benefited the students. Students have engaged enthusiastically with these resources and completed the majority of the tasks set. The results of this study demonstrate that innovative interventions which employ online pre-laboratory videos hold significant potential for improving student preparation and performance in undergraduate food science and technology laboratory classes. Engagement with and completion of preparation tasks before the laboratory session can be thought to positively influence student performance. The positive feedback suggests that the videos are valuable to the learning process despite the extra time required to watch them. Moreover, high-quality interactions with instructors have the strongest and most lasting impact on student retention and achievement in STEM classrooms and this study suggests that online pre-laboratory videos may provide one mechanism to free up more classroom time for such interactions. To apply this model successfully in other food science and technology courses, future research is required to evaluate the LMS learning analytics for student learning and success, interactive videos and the effect of participation and time from both the students and instructors. This study will contribute to future research investigating student perception of pre-labs to ensure the development of a quality food science and technology curriculum.

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AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and research design. V.V Mshayisa planned and taught the course and participated with the professional video team in creating the videos. Material preparation and data collection were performed by V.V Mshayisa and analysis was performed by all authors. M. Basitere gathered the electronic data from Bb and the survey platform, collaborated in compiling questions and analysed data. His main contribution was the discussion of technology in education and student perspectives. Both authors read and approved the final manuscript.

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SUPPORTING INFORMATION

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