Home-based physiology labs in the time of COVID-19 prove popular with medical students

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Abstract

The COVID-19 pandemic and the resulting “lockdown” have forced many medical schools to shift from traditional “face-to-face” teaching methodologies and embrace full online delivery. Although lectures and tutorials are readily communicated by this approach, the execution of laboratory exercises is much more difficult. To overcome these challenges, face-to-face laboratory sessions were replaced by a blended learning approach in which students were provided instructional material online and then required to conduct the laboratory exercises at home. These laboratory exercises made use of easily accessible household materials and mobile applications. A self-report survey was designed to assess students’ perception of their learning experience and attitudes to the home-based laboratory exercises. The survey consisted of 16 questions that students had to respond to using a 5-point Likert scale. Students were also allowed to provide open responses to select questions. Overall, the 80% of students that completed the survey expressed strong satisfaction with their learning experience and were enthusiastic toward home-based laboratory exercises. However, concerns about not being able to complete particular face-to-face exercises that required specialized equipment were expressed. Several students proposed a combined approach going forward. Our results show that home-based laboratory exercises offer a multimodal option that enriches the learning curriculum by engaging students in “hands-on” bespoke practices using inexpensive household materials.

laboratory exercises; medical education; physiology; preclinical

INTRODUCTION

For more than 100 years, training in the basic medical sciences, anatomy, physiology, and biochemistry, has occupied a central and foundational role in medical education. Basic medical sciences are considered core to clinical practice and essential in developing critical thinking, problem solving, and academic rigor (1). Within the delivery of the basic medical sciences curriculum, laboratory exercises are considered an essential component, providing an opportunity for active learning, reinforcement of concepts taught via lectures, and the acquisition and development of experimental skills, scientific literacy, and collaborative learning skills (2).

Over the past decade, online and blended learning have rapidly advanced new and innovative approaches to curriculum delivery for which many medical education specialists have been advocates (3, 4). Blended learning has been found to increase engagement and active learning and improve students’ success compared with face-to-face courses and consequently has become increasingly common in medical education (5–8). Many students have also expressed appreciation for the approaches used and confidence in their level of preparation for more advanced courses (9). Importantly, these are views shared by educators and students alike (10).

Despite the success of blended learning approaches for enhancing the delivery of lectures and tutorials, research on the effectiveness of using blended learning in laboratory exercises is limited and requires further investigation. Generally, online laboratory exercises have been administered with the use of virtual platforms with interactive animations and simulations. These have demonstrated some level of success in terms of student learning and engagement (11–13). However, such virtual laboratories still do not provide students with a “hands-on, real-world” learning experience. In addition, in lower-income countries such simulations can prove expensive.

In this article we report on the use of a novel, home-based, multimodal approach to laboratory exercises. This approach entailed viewing short video demonstrations, constructing equipment out of materials readily available at home, and using smartphone-based applications or printed charts. The potential advantage of such an approach is that it allows students to engage in scientific experimentation without the need to attend laboratory classes in person. In addition, the students’ responsibility for designing the equipment promotes more active engagement with the underlying principles being reinforced by the laboratory exercise.

Consequent to the COVID-19 pandemic, most medical schools have closed classrooms and have been forced to
utilize online learning approaches for curriculum delivery. At the Faculty of Medical Sciences of The University of the West Indies (UWI), St. Augustine, Trinidad & Tobago we have faced similar challenges. Within the Physiology Unit we sought to adjust the delivery of the laboratory-based component of our course with the implementation of home-based laboratory sessions. These efforts were piloted for the course Neuroscience & Behavior, a year two course delivered to dental and medical students. This report explores the effectiveness of home-based physiology laboratories on student learning as well as students’ attitudes to home-based laboratories as a facilitator of their learning experience. We also seek to explore whether there were any predictors of student attitudes to these laboratories including sex, attendance at lectures, and program of study.

## MATERIALS AND METHODS

### Laboratory Teaching

At the Faculty of Medical Sciences, UWI, physiology is taught as a preclinical subdiscipline within a systems-based medical curriculum during the first 2 yr of medical training. During the Neuroscience & Behavior course, students are typically expected to complete four in-person laboratory exercises each lasting between 2 and 3 h. The four exercises are 1) Evaluation of the Somatosensory System—Absolute Pressure Sensitivity and Two-Point Discrimination; 2) Electroencephalogram (EEG) Recordings—Two Experiments; 3) Vision—Visual Acuity, Color Vision, Astigmatism Testing, Near Point of Vision, and Perimetry; and 4) Hearing—Rinne’s Test, Weber’s Test, and Pure Tone Audiometry.

Because of the COVID-19 pandemic public health regulations, laboratory exercises could not be conducted in the traditional face-to-face manner. As a result, students were required to conduct similar exercises within the confines of their homes. Each home-based laboratory consisted of the following. Students were

- required to read about the lab in the laboratory manual prepared for this course;
- asked to watch a video of the lab exercises before performing them;
- given instructions on how to build the experimental apparatus or required to download a smartphone application;
- provided with written instructions on how to conduct the laboratory exercises;
- required to submit a picture of themselves with the apparatus; and
- required to write a report on their results and answer questions provided.

Overall, only one exercise could not be performed, the EEG. This was because of the requirement for specialized equipment that could not be modified for home use. Table 1 highlights how each laboratory exercise was adapted for home-based learning. An example of the apparatus constructed by the students is shown in Fig. 1. Further details that will allow teachers to replicate our home-based laboratories are provided in the Supplemental Materials (available at https://doi.org/10.6084/m9.figshare.14896323). These are the pdf documents that were provided to students.

### Academic Performance

Laboratory sessions were not directly examined in this course. Rather, questions pertaining to the material were asked during the continuous assessment and final examinations. Annually, ~10–12% of the total mark is contributed by questions from laboratory sessions. These questions were extracted and scores totaled to give an evaluation of laboratory performance out of 100%. Historically the examinations have been multiple choice and face to face, but because of the pandemic examinations in 2020/2021 were asynchronous and delivered online. Scores were compared with results from the cohort of students the previous year, 2019/2020. It should be noted that a small component of the continuous assessment scores (0.5%) from 2019/2020 could not be accessed because they were in storage and current “lockdown” regulations do not allow access.

### Survey Instrument

A short 16-item questionnaire was designed to assess students’ perceptions of their learning experience during the laboratory exercises, their attitudes, and their satisfaction with the process and comparison with face-to-face laboratory sessions. Participants were required to answer using a 5-point Likert scale: 1—Strongly Disagree; 2—Disagree; 3—Neither Agree nor Disagree; 4—Agree; and 5—Strongly Agree. The questionnaire took ~10–15 min to complete. Two questions were phrased in the negative and reverse scored to identify rote answering. In addition, students were asked to give open explanations of topics highlighted in the survey. After brief demographic data were provided the following questions were asked:

### Table 1. List of laboratory exercises conducted at home and methodology used

| Laboratory Exercise | Procedure |
|---------------------|-----------|
| **Somatosensory System** | Construction of apparatus at home and execution of laboratory exercise |
| • Absolute Pressure Sensitivity | |
| • Two-point discrimination | |
| **Vision** | Construction of apparatus at home and execution of laboratory exercise |
| • Visual Acuity | |
| • Color Vision | |
| • Astigmatism | |
| • Perimetry | |
| • Near Point of Vision | |
| **Hearing** | |
| • Rinne’s and Weber’s tests | |
| • Audiometry | |

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Perceptions of the learning experience.
- The home-based laboratory instructions were easy to understand.
- The home-based laboratory sessions reinforced topics from lectures and textbooks.
- The home-based laboratory sessions helped me with the understanding of learning objectives for this course.
- Lecture material did not help me understand the purpose of the home-based laboratory sessions.
- Completing the home-based laboratory sessions and assignments helped me do better on quizzes and examinations.
- I was able to develop skills useful for my career by completing the home-based laboratory sessions.

Attitude and satisfaction with the process.
- Performing the home-based laboratory sessions did not increase my interest in this course and the topics.
- Overall, I would recommend the use of home-based laboratory sessions going forward.

Comparison with face-to-face laboratory sessions.
- The time required to complete the home-based laboratory sessions was longer than the time spent in traditional face-to-face laboratory sessions.
- I think that I learn and understand more in a home-based laboratory session than a traditional face-to-face.
- I prefer the home-based laboratory sessions as compared to the traditional face-to-face laboratory sessions.
- My home-based laboratory experience was better than my experience in a traditional face-to-face laboratory session.

Participants
Participants were second-year medical students taking the course Neuroscience & Behavior. Two hundred ninety-three students were registered, of which 235 students (80%) took part in the feedback survey provided. Overall, 155 participants (66%) were female, which is consistent with the population of the class. In addition, 214 students (91%) were completing a medical degree (MBBS), whereas the other 21 were reading for a dental degree (DDS). In terms of lecture attendance, 37 students (16%) indicated they attended ≤50% of the lectures and the other 198 students (84%) attended >50%. Being second-year students, this cohort of students had already been exposed to several face-to-face physiology laboratory sessions during their first year. These focused upon the musculoskeletal and cardiovascular systems and primarily involved computer-based laboratory sessions using BIOPAC systems.

Procedure
This study received ethical approval from the Ethics Committee of The University of the West Indies, St. Augustine, Trinidad & Tobago. The course lasted 8 wk; during the last review session before final examinations, students were invited to give feedback via the online survey.

Data Analysis
All data were analyzed with SPSS v24.0. For academic performance, results for the 2020/2021 cohort were compared with the previous year, 2019/2020. Data are presented as means (standard deviations), and comparisons were made with the Student’s t test. To evaluate the frequency distribution of the survey, responses were grouped into three categories, Agree, Neutral, and Disagree, and percentage responses in each category determined. Chi-square tests were then conducted to analyze the distribution of the responses. Analysis between groups was conducted with the Mann–Whitney U test, for which medians (interquartile ranges) are presented. A significance level of 0.05 was set for all tests.
RESULTS

Academic Performance

The mean score on the laboratory questions for academic year 2020/2021 was 65 ± 15%. For year 2019/2020 the mean score was 66 ± 14%. There was no significant difference in the scores of the two groups (P = 0.47).

Learning Experience

The results for the participants’ learning experience are summarized in Table 2. Overall, the participants expressed satisfaction with their learning experience; for all statements, chi-square analysis demonstrated that a significant proportion of students agreed with the statements. In particular, 81% of students expressed agreement with the statement “The home-based laboratory sessions helped me with the understanding of learning objectives for this course,” yielding a median of 4(1). For the statement “The home-based laboratory sessions reinforced topics from lectures and textbooks,” 94% of students agreed, with a median of 4(0), and 69% of students agreed that the home-based laboratory sessions helped them develop skills useful for their career, with a median of 4(1). For this question students were invited to provide written responses to describe the skills learned, for which 84 responses were recorded. Of these, 60 (71%) focused on acquisition of the clinical skills associated with performing the exercises, whereas 24 (29%) described the acquisition of life skills including communication skills, critical thinking and problem solving, time management, and patience.

Attitudes toward Home-Based Laboratory Sessions

Attitudes to the home-based laboratory sessions were positive, as evidenced by the scores summarized in Table 2, which shows in all cases that a significant portion of students agreed with the statements (P < 0.001). Of note, 58% of students supported the use of these types of sessions going forward [median 4(1)]. Also, 66% of students felt that these sessions increased their interest in the neuroscience course and topics within [median 4(1)]. Students were given the option to provide further additional comments; 47 responses were received. Of these comments, 30 were positive and supportive of the experience, with several indicating that the sessions were fun and engaging. Comments included

“It was a great experience and doing the labs home made me feel more comfortable and less nervous to make mistakes.”

“Home-based labs were very effective and utilised material from home. As opposed to labs at school it allowed for each person to be practical and thus enabling a better understanding of the topics”

Table 2. Summary results assessing learning experiences and attitudes toward home-based laboratory exercises

| Statement                                                                 | Median (IQR) | % A | % D | % N | Chi-Square Test |
|---------------------------------------------------------------------------|--------------|-----|-----|-----|-----------------|
| Learning Experience                                                      |              |     |     |     |                 |
| The home-based laboratory sessions reinforced topics from lectures and textbooks | 4(1)         | 96  | 2   | 2   | $\chi^2(2) = 411.9; P < 0.001$ |
| The home-based laboratory instructions were easy to understand.           | 4(1)         | 92  | 4   | 4   | $\chi^2(2) = 30.9; P < 0.001$ |
| The home-based laboratory sessions helped me with the understanding of learning objectives for this course. | 4(0)         | 91  | 2   | 7   | $\chi^2(2) = 353.5; P < 0.001$ |
| Lecture material helped me understand the purpose of the home-based laboratory sessions. | 4(0)         | 78  | 11  | 11  | $\chi^2(2) = 216.1; P < 0.001$ |
| I was able to develop skills useful for my career by completing the home-based laboratory sessions. | 4(1)         | 69  | 9   | 22  | $\chi^2(2) = 142.7; P < 0.001$ |
| Completing the home-based laboratory sessions and assignments helped me to do better on quizzes and examinations. | 4(1)         | 55  | 14  | 31  | $\chi^2(2) = 59.9; P < 0.001$ |
| Attitude and Perception                                                  |              |     |     |     |                 |
| Performing the home-based laboratory sessions increased my interest in this course and the topics. | 4(1)         | 66  | 15  | 19  | $\chi^2(2) = 111.5; P < 0.001$ |
| Overall, I would recommend the use of home-based laboratory sessions going forward. | 4(1)         | 58  | 19  | 23  | $\chi^2(2) = 66.3; P < 0.001$ |
| Comparison with Face-to-Face Sessions                                     |              |     |     |     |                 |
| The time required to complete the home-based laboratory sessions was longer than the time spent in traditional face-to-face sessions. | 3(2)         | 47  | 28  | 25  | $\chi^2(2) = 16.9; P < 0.001$ |
| I think that I learn and understand more in a home-based laboratory session than a traditional face-to-face lab session. | 3(2)         | 41  | 25  | 34  | $\chi^2(2) = 8.8; P = 0.01$ |
| I prefer the home-based laboratory sessions as compared to the traditional face-to-face laboratory sessions. | 3(2)         | 38  | 32  | 30  | $\chi^2(2) = 2.4; P = 0.30$ |
| My home-based laboratory experience was better than my experience in a traditional face-to-face laboratory session. | 3(2)         | 31  | 26  | 43  | $\chi^2(2) = 4.0; P = 0.13$ |

Table highlights the percentage of responses to each item within the survey. A, strongly agree; D, strongly disagree; IQR, interquartile range. Chi-square analysis was performed to determine whether students preferentially chose one option; significance set at $P < 0.05$. *Items were presented in the negative in actual questionnaire and reverse scored. **Students who attended >50% of the lectures all scored these significantly more positively, P < 0.05. Female students all scored these significantly more positively than male students, P < 0.05.
“Once it’s possible to do labs at home, it shows the student how these concepts can be applied in simple ways...in daily life...it relates more to life rather than making it a more technical concept in a lab...it helps you relate more...but they are fun either way.”

“They were fairly simple and very enjoyable to conduct...They also encouraged me to read more on the topic in order to understand them.”

“The home-based lab was exciting to carry out and I learnt more when having to create my own apparatus.”

There were two students who had negative comments. One noted, “Without guidance from a professional, I did not learn anything from this laboratory. Amongst the other assignments, it was also very time-consuming.” An additional five students indicated a preference for face-to-face laboratory sessions, and a further nine comments highlighted challenges with the instructions or sourcing materials because of the pandemic.

Comparison with Face-to-Face Laboratory Sessions

In comparison to face-to-face laboratory sessions, 41% of students felt that they learned more from the home-based session, with 25% disagreeing, yielding a median of 3(2). Thirty-eight percent of students indicated that they preferred home-based exercises versus 32% who did not [median 3(2)]. Similarly, when asked about the experience, 31% of students felt they had a better experience at home versus 29% who felt that face-to-face exercises provided a better experience [median 3(2)].

Comparisons

Differences in the responses between dental students and medical students were not significant except for the question on skills acquisition for future practice. Here a greater proportion of medical students agreed with the statement that the exercises allowed them to develop skills useful for their future career compared with dental students [median values 4(1) vs. 3(2), U = 3,328; P < 0.001]. In terms of attendance at lectures, there were significant differences on several questions, as seen in Table 2. These focused on the benefit of the home-based laboratory exercises in terms of examination performance, skills acquisition, and attitude. In all cases, those who attended ≤50% of the lectures held more unfavorable views. Finally, in many cases females scored higher on the questions compared with males, suggesting a general preference for the home-based laboratory exercises (Table 2).

DISCUSSION

Our main findings are that basic medical sciences students report a successful learning experience utilizing home-based physiology laboratory exercises. Over 75% of students reported that home-based laboratories were easy to do, reinforced lecture material, and aided their learning of the course objectives. In addition, the majority of students indicated that performing these laboratories allowed them to develop skills useful for their career and benefited their performance during examinations.

We also noted that the academic performance of the students on the home-based laboratories was almost the same as the cohort of students from the previous year (mean score: 65% vs. 66%) for whom the traditional face-to-face format of laboratory exercises was used. Such findings are not unusual, as others studies exploring academic performance in blended learning laboratory courses have reported similar findings (14, 16). It thus can be argued that, at the very least, given that there was no clear difference in test performance, the home-based practicals are just as effective in providing the requisite knowledge but at the same time still provide the students with a hands-on learning experience and the development of skills. In addition, it is worth noting that this process took place in the midst of the COVID-19 pandemic, when the challenges and stresses experienced by medical students globally were magnified (15). Even though we did not measure stress among our students, the perceived meaningful engagement expressed by the students with the home-based laboratories may have helped to counteract some of the challenges to learning currently being faced in this pandemic.

With the advent of blended learning, most laboratory exercises are conducted with virtual platforms and simulations. Although useful, these are limited, as they do not allow a hands-on experience and the actual development of skills. Our results show that 69% of students felt the home-based approach allowed them to develop skills useful for their career. Most dental students (67%), however, did not agree with this statement, which may reflect the fact that these exercises have less relevance to their future clinical practice. In addition to the development of clinical skills, we propose that home-based exercises also help to develop active learning and critical thinking; almost 30% of the comments received highlighted such benefits. An additional benefit is that a home-based approach is extremely cost-effective. The cost of face-to-face laboratory exercises is increasingly being highlighted as a potential obstacle for countries with limited resources, such as some of the developing island states within the region. Home-based laboratory exercises therefore offer a multimodal, hands-on experience for all students that in combination with virtual laboratories and simulations can substantially reduce the requirement for all but the most essential face-to-face laboratory activities (17).

We found that students had a favorable impression of the home-based laboratories, with the majority of them indicating that this approach to learning increased their interest in the subject matter (66%) and recommending their use going forward (58%). This was supported by several of the open-ended comments in which students detailed how the process provoked active engagement with the material and a deeper understanding of topics. However, students who attended <50% of lectures had more negative views about their experience. This group did not report reduced learning but rather did not find that the home-based exercises developed useful skills or improved their performance on examination, leading to an overall more negative experience. The reasons for this are unclear. Issues such as lack of attendance at lectures and reduced engagement with the home-based laboratory exercises suggest that this demographic may be challenged with issues of motivation or may be suffering mental health challenges associated with the pandemic (18).
When students were asked to compare their learning and overall perception of the process with their experience with traditional face-to-face laboratories, the results were inconclusive. There was an almost even split between those who preferred home-based laboratories and those who preferred face-to-face laboratories. These feelings were echoed in the comments, with suggestions that a blended approach incorporating facets of both would be ideal. This is not surprising because, despite the benefits of the home-based approach, there were some exercises such as the EEG that could not be performed because of the need for specialized equipment. A recent report also noted a similar finding in the field of microbiology, with the majority of students (89%) also advocating a blended learning approach combining virtual and face-to-face laboratory exercises (19). Interestingly, in all cases female students were more likely to learn and advocate the use of home-based laboratories compared with their face-to-face experience.

As in all research, this study has limitations that must be noted in considering the results. In particular, we made use of a self-report survey, which can be subject to social desirability bias. We sought to eliminate this by administering the survey after the laboratory sessions were completed and making the survey anonymous. Also, we recognize that the novelty of the use of home-based laboratory exercises for one course might be partially responsible for the positive responses and that this might not be replicated if this was the standard method of training. However, our data do provide evidence for further trialing of such endeavors in the future.

In conclusion, our results show that the use of home-based laboratory exercises is an effective method for reinforcing the physiology learning objectives within a basic medical sciences curriculum. Students reported a good learning experience, performed well in their examinations, and had an overall favorable impression of this approach. We suggest that this approach can form a core part of a blended learning curriculum that can stimulate greater engagement with the teaching material and more foster more active learning. In addition, we suggest that this approach will also provide a low-cost alternative to more traditional methods that can be utilized in situations of resource constraints.

SUPPLEMENTAL DATA
Supplemental Materials: https://doi.org/10.6084/m9.figshare.14896323.

DISCLOSURES
No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS
F.F.Y., J.M., and E.M.D. conceived and designed research; F.F.Y. and J.M. performed experiments; F.F.Y. analyzed data; F.F.Y. and J.M. interpreted results of experiments; F.F.Y. prepared figures; F.F.Y. and J.M. drafted manuscript; F.F.Y., J.M., E.M.D., and J.M. edited and revised manuscript; F.F.Y., J.M., E.M.D., and J.M. approved final version of manuscript.

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