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This mixed methods study explored the impact of PocketLab interactive mobile sensors on science content knowledge among undergraduate students in an algebra-based physics laboratory course. The study also examined students' perspectives and experiences using PocketLab to learn class concepts. While no statistically significant differences were found between the control and treatment groups for items evaluating definitions and conceptual mastery, the control group outperformed the treatment group on problem-solving items. This difference may be due to the alignment of traditional Vernier technology experiments with the analytical problem-solving approach emphasized in lectures. Despite this, students using PocketLab reported greater flexibility and stronger connections to real-world applications. Qualitative analysis further explained these results and provided insights into students' experiences. The study concluded that while Vernier technology may be better suited for problem-solving, PocketLab enhances engagement, understanding, and the overall learning experience by facilitating real-world connections.

Keywords: interactive mobile technology, science, student experiences, student perspectives, attitudinal survey, mixed methods

Introduction

Interactive mobile technology has many benefits for the science classroom. Research shows that it has the potential to support both traditional and innovative teaching methods (Lan et al., 2007; Roschelle et al., 2010), exploratory student-centered learning outside of the classroom (Lin et al., 2012), and game-based instruction (Klopfer et al., 2012). Interactive mobile technologies promote innovative educational techniques and strategies to facilitate higher-order thinking skills, problem-solving, and knowledge acquisition. Research shows that integrating interactive mobile technologies can encourage lifelong learning. According to Frohberg (2006), mobile technology allows for more flexibility, spontaneity, and ad hoc adaptability, which benefit learners with different learning styles and processing abilities. Research has been conducted on a variety of interactive mobile technology platforms in science classrooms and their impact on students learning and experiences (Bayar & Kurt, 2021; Ekin et al., 2020; Fuchsova & Korenova, 2019; Gomez-Espina et al., 2019; Teri et al., 2014; Vieyra et al., 2020; Zhai et al., 2019). Previous studies have explored the effects of various interactive mobile technology platforms on science learning in K-12 and higher education settings. PocketLab Science Everywhere System is an interactive mobile platform that enables students to collect, visualize, and analyze live data with one hand-held device. The versatility and portability of PocketLab, which enable it to be attached to various objects for experimentation, bring a unique dimension to science education. Its capacity to record multiple types of data in real-world scenarios aligns with the need for increased flexibility, spontaneity, and ad hoc adaptability in learning environments, as proposed by Frohberg (2006). Although previous research has evaluated the impact of different interactive mobile technologies in science classrooms, the effect of PocketLab interactive mobile technology on students' learning in post-secondary science classroom settings has not been studied. Given its characteristics, it is essential to investigate whether integrating PocketLab technology in science laboratory classrooms enhances student learning outcomes and experiences compared to commonly used Vernier technology that cannot be used outside the traditional laboratory settings.

This mixed methods study aimed to examine how PocketLab interactive mobile sensors affect the acquisition of science content knowledge for undergraduate students enrolled in an algebra-based physics laboratory course. In addition, the study aimed to explore students' perspectives and experiences with PocketLab interactive mobile sensors. The research questions guiding the study included:

1. What is the effect of PocketLab interactive mobile sensors on the acquisition of content knowledge for undergraduate students enrolled in an algebra-based physics laboratory classroom?

2. What are students' experiences and perspectives about using PocketLab interactive mobile sensors in an algebra-based physics laboratory classroom?

3. How does integrating quantitative and qualitative data inform the use of PocketLab interactive mobile sensors in an algebra-based physics laboratory classroom?

Applying a mixed methods approach that combines both quantitative and qualitative data enhances the robustness of the study. The mixed methods approach not only provides a more comprehensive understanding of the issue under investigation but also allows for triangulation, enabling a more thorough validation of the findings and contributing to the overall rigor and validity of the study (Creswell & Plano Clark, 2018). The study will inform practitioners, researchers, and policymakers about the impact of PocketLab interactive mobile sensors on post-secondary students' learning outcomes and their perspectives and experiences with this technology in a science laboratory classroom.

Literature Review

In the literature review section, we first discussed the PocketLab and Vernier technology used in this study to provide an overview of their features and characteristics. It is essential to highlight that PocketLab is one example of an interactive mobile technology that can be integrated into instructional settings in a science classroom. Numerous other mobile technologies are being incorporated into different science classroom settings. No studies have been conducted that focused explicitly on integrating PocketLab technology. Therefore, the literature review in this study focuses on the effects of various interactive mobile technologies on students' content knowledge and their perspectives and experiences with interactive mobile technologies in science classroom settings.

Technology

The definition of technology in this study relied on implementing two technologies and their components into the physics laboratory curriculum: Vernier Science Education Software and the PocketLab Science Everywhere System.

Vernier Science Education Software is the most common technology used in introductory-level physics classrooms to perform experiments (http://www.vernier.com). The Vernier technology includes an array of items like the LabQuest II interface, force sensor, motion sensor, photogate sensor, and force plate. In addition, other accessories were utilized to complement the instrument used and to prepare a proper and optimal experimental setup (i.e., carts, cart tracks, etc.). Vernier technology offers creative ways to teach and learn STEM disciplines. Vernier technology provides opportunities to enhance STEM learning, increases understanding, builds students' critical thinking skills, and supports STEM practices described in Next Generation Science Standards (NGSS). In this study, students in the control group were engaged with Vernier technology.

The PocketLab Science Everywhere System is an interactive mobile technology that provides real-world science learning experiences, includes data sensors and hands-on lab lessons, and offers flexibility and multi-functionality in one portable hand-held device (https://www.thepocketlab.com/). The PocketLab interactive mobile sensor is a lightweight, compact, versatile device conveniently built as a single unit. This sensor fits in the palm of a hand and can measure variables such as pressure, magnetic field, temperature, height, and acceleration. The PocketLab sensor collects and plots data simultaneously when paired with a device. It differs from the Vernier interface in that no wires are needed to transfer data. This, in combination with the sensor versatility, provides a high degree of flexibility as to which experiment students can perform. Students in the treatment group engaged with the PocketLab interactive mobile technology.

Experimental setup with Vernier technology used the LabQuest II interface. This device collected data and provided capabilities to analyze it immediately upon collection and without exporting it to another software. The interface connects directly to a sensor through a cable to complete the data collection. In contrast to the PocketLab sensor, each Vernier sensor only measures the one variable for which it was built. Another aspect of Vernier technology is the accessories accompanying the experimental setup. For example, when studying the motion of an object, Vernier offers many accessories like carts, cart tracks, bumpers, etc, to name a few, that enhance the experiment's accuracy by minimizing non-idealities often encountered, like friction and drag resistance. This setup provides an advantage over the PocketLab sensor because the experimental setups resemble the ideal cases frequently presented in textbooks. On the other hand, this type of accessory constrains the experiments' flexibility. It limits their setups to only a few configurations, rendering a laboratory experience that may not align with students' preferences or interests.

Unlike Vernier technology, PocketLab technology allows students to move beyond the in-class laboratory setting and its predetermined setups. Instead, they can explore and relate the lab experience to what matters to them and what interests them. For data analysis processes, the PocketLab sensor data are exported to Microsoft Excel for processing and analysis, in contrast to the interface used in Vernier technologies. The flexibility inherent in the device does come with a tradeoff. The PocketLab app does not allow for data analysis after the data collection process is finalized, nor does it minimize non-idealities like friction, air resistance, wind currents, etc. The mathematical techniques used to manipulate the data to calculate the desired variable were difficult for students and subjected them to rigorous training for analysis. A brief comparison of the technologies is shown in Table 1, representing the features implemented in this study.

Table 1
A Comparison of Vernier and PocketLab Technologies

	Vernier	The PocketLab
Equipment	• Consists of many sensors, each measuring a specific variable. • Often requires the use of accessories to complete an experimental setup.	• Consists of a small portable single-unit with built-in multi-sensorial capabilities. • The user determines the use of accessories (if any).
Data Collection	• Real-time data collection with visual graphs.	• Real-time data collection with visual graphs.
Data Transfer	• A cable was needed to connect the sensor to the interface. • Data was exported to the participant's computer using a USB drive or wireless export to their email account. A tedious setup was required for wireless exports.	• The sensor connects wirelessly to any smart device or computer. • Data was saved on a smart device and exported to the participant's computer via email—a fairly straightforward process.
Data Analysis	• Each sensor measures a specific variable. • The interface allows for data analysis in the device immediately after collection. • Many options for mathematical analysis.	• Requires complex analytical manipulation to obtain certain variables. • Does not allow for data analysis. Data was exported to Excel for analysis.

It must be emphasized that both technologies are extraordinary pedagogical tools. This study aimed to explore the effects one technology might have over the other in the laboratory classroom. One aspect to be reminded of is that both technologies have continued to evolve in their respective ways since the implementation of this study.

Effects of Interactive Mobile Technology on Students' Content Knowledge

Research on the integration of mobile technology into science classrooms is mixed. Some studies concluded that integrating mobile technologies affected students' grades, achievement, understanding, and learning growth in a positive way (Bayar & Kurt, 2021; Ekin et al., 2020; Fuchsova & Korenova, 2019; Gomez-Espina et al., 2019; Vieyra et al., 2020). For example, Gomez-Espina et al. (2019) reported on the results of a quantitative study examining Socrative, an interactive mobile technology tool, for performance improvement in STEM college classrooms. Science and engineering undergraduate students enrolled in geology courses participated in the study. Students in treatment groups experienced instruction with Socrative interactive technology, while students in the control groups experienced traditional "business as usual" instruction. Midterm and final grades were used to compare students' knowledge of course content, and a survey was used to explore students' perceptions about their experience with Socrative interactive technology. Students in the treatment groups showed more improvement in midterm and final course grades than students in the control groups. In addition, absenteeism decreased in students in treatment groups, and they had positive perceptions of Socrative interactive technology, commenting on a better understanding of the subject matter and increased motivation, among others. Bayar & Kurt (2021) reported similar results after conducting a mixed methods study to examine the effects of mobile technology on students' academic achievement in science middle school classrooms. The authors conducted a quasi-experiment with pre-and post-tests to measure student achievement and qualitative interviews with students in the experimental group regarding their experience with the mobile technology that they were engaged within the classroom. Findings revealed that "the academic achievement of the experimental group students was higher than the control group" (Bayar & Kurt, 2021, p. 260). In addition, the analysis of the qualitative interview data revealed that students were satisfied with the mobile technology-aided learning that they experienced.

Vieyra et al. (2020) examined a gamified component of the Android Physics Toolbox Sensor Suite app that introduces learners to fundamental physics principles. The tool was implemented in a variety of contexts, both academic and informal settings, with K-12 students, undergraduate physics students, and during teacher professional development workshops. Physics ToolBox Play allowed students to collect data and use the application for processes they observed daily. Students collected science data through the app features such as an accelerometer, magnetometer, sound, and a light meter and could see physical relationships based on the data they observed in real-life situations that surrounded them. Veiyra et al. (2020) reported that "students of all levels and abilities were successful in demonstrating growth in their understanding of physics" (p. 5). Similarly, Ekin et al. (2020) reported improvements in students' understanding of science concepts when the do-it-yourself light wave sensing kits were integrated during the on-campus summer program for high school senior students and incoming first-year undergraduate students at Oklahoma State University. The light wave sensing kits were intended to make wireless concepts more understandable by linking fundamental concepts with student-relevant technologies such as solar cells, visible lights, and smartphones. Data was collected through pre- and post-assessments of students' content knowledge and observations. Fuchsova and Korenova (2019) collected quantitative questionnaire data, qualitative observations, and video recordings of students' work to explore the use of augmented reality Brain iExplore and Anatomy 4D mobile technology applications in an undergraduate biology class. Students in this study worked in small groups, implementing the tool to learn class concepts. The study concluded that by using Brain iExplore and Anatomy 4D interactive mobile technology applications, students improved their knowledge of the subject matter and experienced an increase in motivation and creativity.

Some studies reported no difference in student achievement and understanding of content when mobile technology platforms were integrated into the classroom (Gümüş & Gençoğlu, 2020; Lopez-Moranchel et al., 2021) and discussed other factors that played a role (Teri et al., 2014; Zhai et al., 2019). For example, Lopez-Moranchel et al. (2021) conducted a quasi-experimental study to evaluate the impact of KinematicLab mobile technology in an undergraduate applied biomechanics class. Undergraduate students in an experimental group used KinematicLab to measure kinematic and kinetic parameters to assess biomechanics' physical concepts. In contrast, students in the control group used conventional instruments and materials. T-test analysis found no statistically significant differences between the control and treatment groups regarding learning outcomes and knowledge acquisition after the intervention. The study by Gümüş & Gençoğlu (2020) compared control and treatment groups in terms of their learning outcomes in undergraduate anatomy courses when Quizizz interactive technology was used to learn content in the course. In this study, the treatment group used the Quizizz interactive application for 14 weeks, and the control group used a traditional approach to learning. The study concluded that there was no statistically significant difference in students' test scores on final exams. However, there was a statistically significant difference in scores on mid-term exams. Zhai et al. (2019) reported that teachers' use of interactive learning technologies in physics high school classrooms positively correlated with students' achievement of physics concepts, concluding that teacher use of interactive technologies played a role in increased students' learning outcomes. In this study, pre- and post-achievement tests were administered at the beginning and the end of the semester, respectively, and multilevel hierarchical linear models were used to analyze the data.

Students' comfort level with interactive mobile technology also affected how it benefitted them. For example, through student assessment measures and a survey, Teri et al. (2014) studied the use of NutriBiochem mobile technology in undergraduate biochemistry and nutrition courses. Teri et al. (2014) found a significant positive relationship between the frequency of use of the application and students' final course grades. Students with higher comfort levels with NutriBiochem technology accessed the application more frequently and had higher course grades.

Students' Perspectives and Experiences with Interactive Mobile Technologies

The research examined students' perspectives and experiences regarding integrating interactive mobile technologies into classroom instruction (e.g., Fuchsova & Korenova, 2019; Lopez-Moranchel et al., 2021; Reyna, 2021; Serpagli & Mensah, 2021). For example, Reyna (2021) conducted a mixed methods study to examine the use of SPARKPlus student peer-review applications in an undergraduate science education classroom. Data was collected through surveys, open-ended questions, students' grades, LMS logs, and group work to ensure methodological triangulation. The study concluded that students had positive perspectives towards the application and reported high engagement in their learning and increased creativity, teamwork, opportunities for self-expression, and a fun factor introduced by the application. In a qualitative ethnographic study, Serpagli & Mensah (2021) explored female high school students' attitudes toward using an interactive mobile platform in a biology classroom. Data was collected through questionnaires, focus groups, and interviews. The study reported students' favorable perspectives towards using the platform and suggested that the application made the learning experience more participatory and comfortable for students and allowed students to incorporate their interests and youth culture as well as out-of-class beyond the school learning. Fuchsova & Korenova (2019), Gomez-Espina et al. (2019), Lopez-Moranchel et al. (2021), Teri et al. (2014), Vieyra et al. (2019) reported similar outcomes. Some studies found no significant difference in students' perspectives toward interactive mobile technology platforms despite finding improved learning outcomes in students who engaged with those technologies (Gümüş & Gençoğlu, 2020).

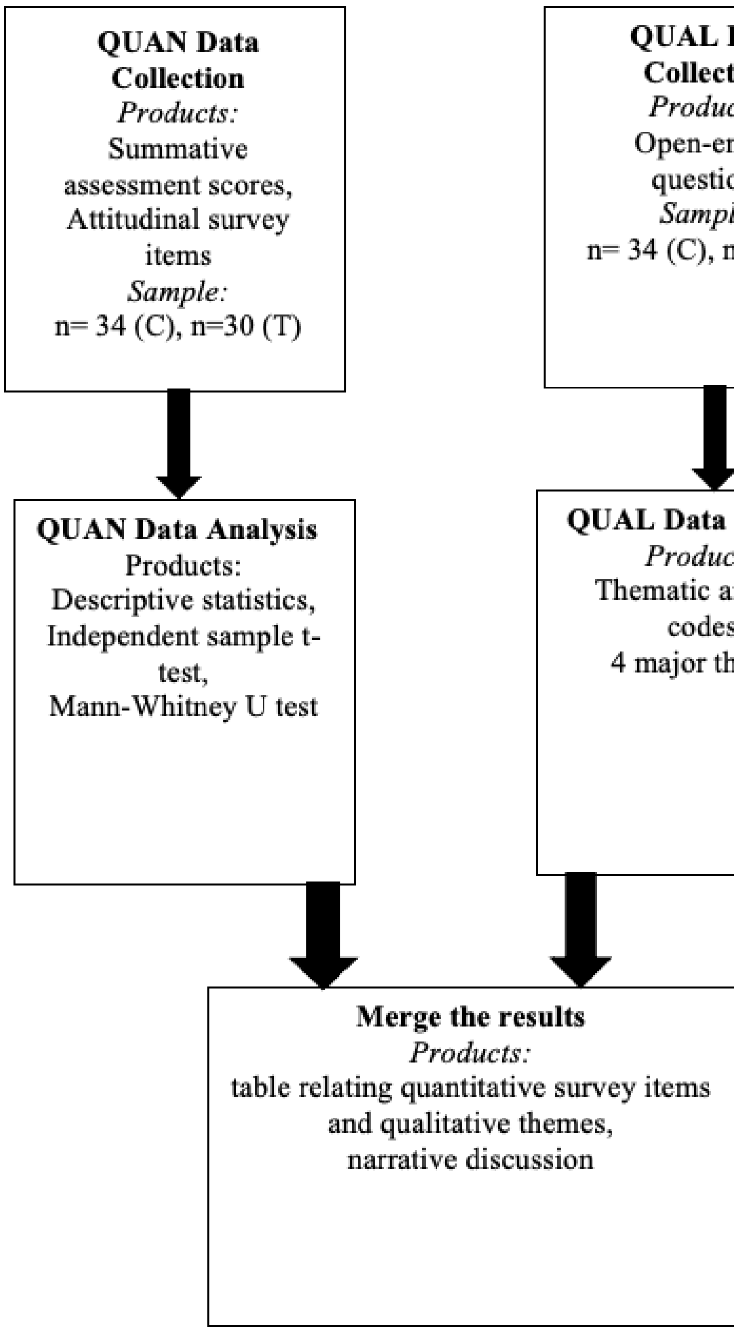
Positive perspectives toward different interactive mobile applications were associated with increased interest in the subject matter. Multiple studies mentioned that the integration of interactive mobile technology platforms increased students' interest in science courses that they participated in and consequently positively influenced their perspectives (Bayar & Kurt, 2021; Ekin et al., 2020; Lopez-Moranchel et al., 2021; Zhai et al., 2019). Studies attributed students' favorable perspectives and experiences to greater motivation, creativity, and enhanced learning experience (Fuchsova & Korenova, 2019; Teri et al., 2014).

Methodology

Type of Design

The study utilized a convergent mixed methods design (Creswell & Plano Clark, 2018). This type of design places equal weight on both quantitative and qualitative data and implies concurrent but separate data collection and analysis (QUAN+QUAL) that are merged in the interpretation phase of the study (Creswell & Plano Clark, 2018). With this type of design, the researcher collects different but complementary data that compensates for weaknesses and draws on the strengths of both analyses (Caracelli & Greene, 1993). Figure 1 shows procedures in convergent mixed methods design applied in this study.

Figure 1



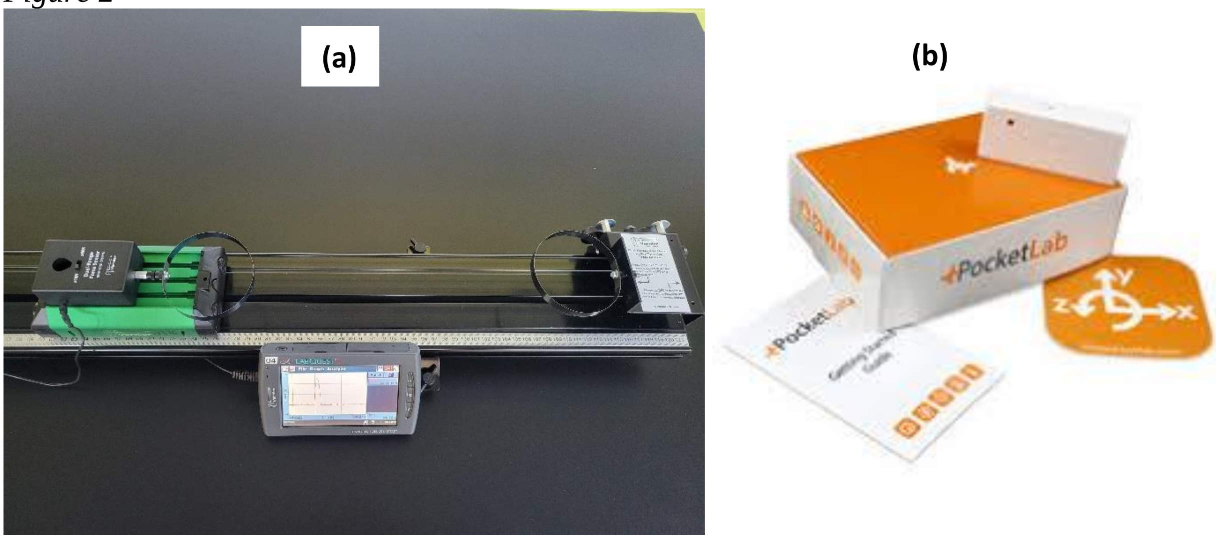
Visual Diagram of the Procedures in the Study

Apparatus and Materials

The apparatus used in this study consisted of Vernier technology and the PocketLab sensor (Figure 2). The IRB permission was secured, and the study was conducted during two semesters. During one semester, students enrolled in an algebra-based physics laboratory course at a private

Midwestern university served as a control group and engaged with Vernier technology. During the second semester, a different group of students enrolled in the same course engaged with the PocketLab sensor and served as a treatment group. The same instructor of record taught the course both semesters. All students enrolled in the course were invited to participate in the study.

Figure 2



An Example of the Components Needed when Using the (a) Vernier Technology and (b) PocketLab Sensor

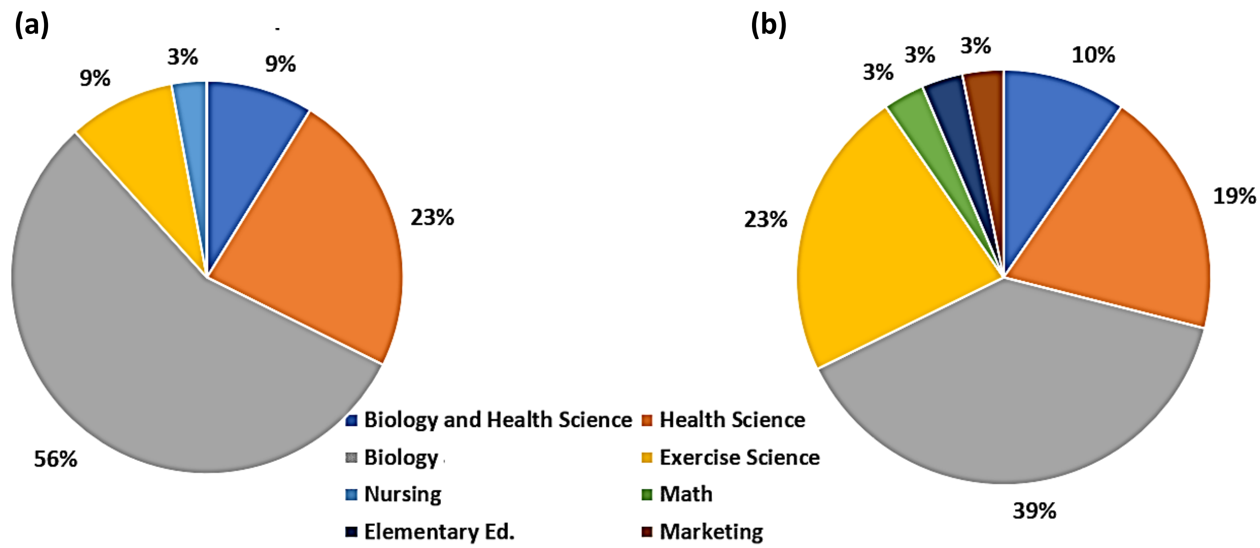
The materials developed for this study included a summative assessment and an attitudinal survey. The summative assessment had 37 questions and was comprised of three sections. The first section focused on definitions with 22 questions for which participants had to match the science term with its definition. The second section assessed participants' concept comprehension and included ten questions. The third section of the summative assessment focused on participants problem-solving skills using analytical thinking questions. There was a total of five questions in this category.

The survey comprised 22 items, including a close-ended 5-point Likert scale and qualitative open-ended questions. The questions focused on collecting demographic information of the participants, such as age, gender, year in college, etc., and information about the participants' perspectives, experiences, and preferences regarding the lab instruction they experienced.

Participants

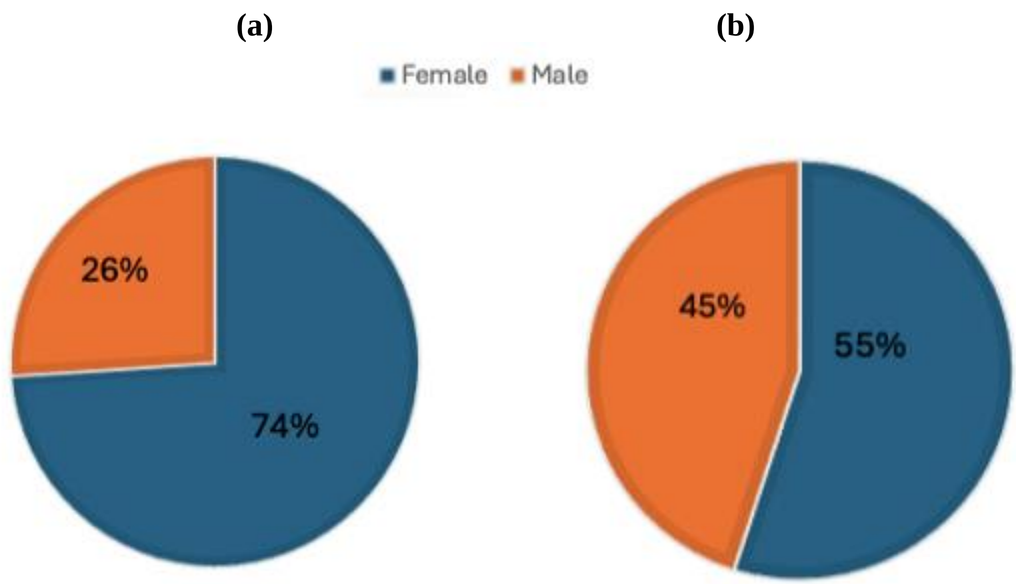
The participants in this study were undergraduate students enrolled in an algebra-based physics laboratory course offered at a Midwestern private institution. A total of N= 34 students were engaged with the Vernier technology and were defined as the control group. The other group consisted of N = 30 participants who experienced PocketLab technology and were defined as a treatment group. Figures 3 and Figure 4 include the demographics of the groups. Participants in the control group were 25 % male and 75 % female students. The treatment group included 45 % male and 56 % female students. Female students represented the majority of participants in both groups. Participants in both groups ranged in age from 18 to 22 and were predominantly juniors and seniors. Most participants were majoring in biology and health & exercise sciences and had no previous experience with PocketLab technology. When comparing the means, this study met the recommended minimum sample size of 30 participants in each group (Cohen, 1988).

Figure 3



The Participants' Demographics by Major between the (a) Control and the (b) Treatment Groups

Figure 4

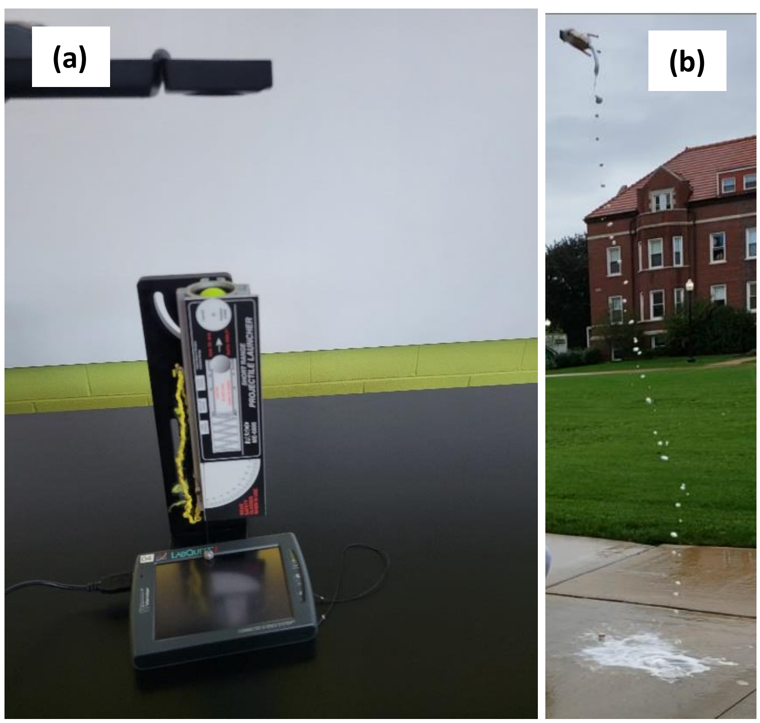


The Participants' Demographics by Gender between the (a) Control and the (b) Treatment Groups

Procedures

The participants in this study were enrolled in the algebra-based physics laboratory course. During this time, the participants from both groups were engaged in weekly experiments, exposed to the same curriculum topics, and followed the same procedures. The same course instructor was teaching students in both control and treatment groups. The groups differed in the type of technology used throughout the semester to collect data and complete their experiments and in the designed experimental setup. For example, under the developed curriculum, the participants in both groups completed an activity on "Projectile Motion" during week #5 of the semester. The control group employed Vernier technology to systematically explore this type of motion using a motion sensor, projectile launcher, and the LabQuest I interface. A simplified version of the setup is shown in Figure 5. The treatment group used the PocketLab sensor to study the exact type of motion with a different experimental setup. The sensor was attached to a homemade rocket (a plastic bottle filled with a predetermined amount of vinegar and baking powder), and data was collected from takeoff to landing.

Figure 5



The Experimental Setup when the (a) Control and the (b) Treatment Groups Explored the Topic of Projectile Motion

Validation

Several validation techniques were used in this study. The survey instrument was developed after a thorough literature review and expert validation. According to Polit and Beck (2006), using experts' feedback to systematically review the survey's content to improve the overall quality and representativeness of the scale items is essential in a survey development process. Face and content validity were conducted to ensure the accuracy of the developed survey instrument (Creswell, 2015). Both face and content validity were confirmed by asking experts and non-experts to review the survey instrument. Experts validated the key areas such as representativeness, clarity, relevance, and distribution.

According to Hatch (2002), triangulation is one way to improve confidence in reported data. The survey consisted of items focused on collecting quantitative Likert scale data and qualitative open-ended questions. Parallel questions addressing experiences in the physics lab made data more comparable.

A detailed description of the findings is another qualitative validation procedure that is applied in this study to allow readers to make their own decisions regarding the transferability of the findings to other settings (Lincoln & Guba, 1985; Merriam, 1988). Merriam (1988) suggested that a researcher needs to clarify their own biases for the reader to help better understand the position and personal biases that may impact qualitative analysis and interpretation. The researchers believe in the benefits of interactive mobile technology in the classroom if it is integrated and scaffolded appropriately. However, the researchers' own beliefs about the effects of interactive mobile technology on learning did not influence the data analysis in the study.

Data Analysis

The data from the summative assessment and the attitudinal survey was analyzed using IBM's Statistical Package for the Social Sciences (SPSS) software. To answer research question one, an independent sample t-test was performed to determine if there was a statistically significant difference between the means of the test scores for participants who experienced the physics laboratory that integrated Vernier technology (control group) and those who participated in a laboratory that implemented the PocketLab interactive mobile technology (treatment group). To answer research question two, both qualitative thematic analysis and a Mann-Whitney U test were performed on a reduced 5-point Likert scale item from the attitudinal survey to compare if there was a significant difference in the mean rank between the two groups when comparing the items that relate to the participants' laboratory experience and perspectives when using their respective technologies. Then, the data were normalized to enhance the distinction between those participants with a favorable (or positive) experience and those with an unfavorable (or negative) lab experience. The Mann-Whitney U test uses "the data from two separate samples to evaluate the difference between two treatments" (Gravatter & Wallnau, 2007, p. 641). Individual scores in the two samples are rank ordered. Mann-Whitney U test does not require homogeneity of variance or normal distributions, but it requires independent observations and assumes that the dependent variable is continuous (Gravatter & Wallnau, 2007). To answer the third research question, quantitative and qualitative data analysis results were merged as suggested by procedures for convergent mixed methods design (Creswell & Plano Clark, 2018).

This study used quantitative data to examine differences in students' learning and students' perspectives. The qualitative data provided further insights and explored students' perspectives and experiences with PocketLab interactive technology in an undergraduate physics laboratory classroom. Quantitative and qualitative data were collected to bring greater insight into the problem than would not be obtained by either type of data separately (Creswell & Plano Clark, 2018). The researcher conducted preliminary exploratory analysis by reading through qualitative text data several times and writing memos on the margins of the data to retrieve general ideas. After the researcher identified text segments and assigned code words, codes were collapsed into themes. Four themes emerged: *Enhanced Understanding of Science Concepts, Experiencing Real-life learning, Engaging in Learning by Doing,* and *Limitless Possibilities*. Qualitative results involved a discussion of themes and their evidence. Multiple perspectives of participants were described, and quotes were cited to support the data. In the current study, statistical analysis of the quantitative data was performed concurrently with the qualitative data coding. The researcher merged two data sets in the second stage to develop a complete picture.

Results

Effect of PocketLab Interactive Mobile Technology on Students' Content Knowledge

The quantitative data was collected from the summative assessment and the attitudinal survey. The summative assessment evaluated students' knowledge and skills of concepts discussed during the laboratory course. An independent two-sample t-test was performed to determine if the means from the summative assessment scores between the two groups differed significantly (Table 2). The control group (N = 34) that received the traditional instruction with Vernier technology (M = 25.5, SD =3.7) scored significantly better than the treatment group (N=30) that received the PocketLab instruction (M = 22.7, SD =5.9); t (48)=2.3, p = 0.028.

Table 2
Results of a t-test Comparing Summative Assessment Scores for Students in Control and Treatment Groups

Group	n	Mean	SD	t-value	df	p-value
Control	34	25.5	3.7			
Treatment	30	22.7	5.9	2.3*	48	0.028

*$p < 0.05$

To further explore the effect of PocketLab instruction on students' learning, the summative assessment was divided into three categories: definitions, concepts, and problem-solving skills. Analysis revealed a statistically significant difference in the total scores between participants (N=34) exposed to Vernier technology (M = 2.9, SD =1.2) and participants (N=30) who experienced PocketLab instruction (M = 1.6, SD =1.1); t (62) = 4.2, p < 0.001) when assessing problem-solving skills. No statistically significant differences were found between the control (M = 17.4, SD =2.7) and treatment (M = 16.2, SD =4.1) groups when assessing definitions (t (49 = 1.3, p = *0.209*) or conceptual mastery (control group; M = 5.3, SD = 1.5) (treatment group; M = 4.8, SD = 1.9); t (62) = 1.2, p = 0.249. This result could be attributed to the type of experiments performed with traditional instruction with Vernier technology, in which the thought process to solve analytical problems resembles those discussed in the class lecture portion. In addition, the geometry of the experimental setups implemented in the instruction with Vernier technology was similar to the geometry embedded in the analytical problems participants solved during the lecture.

Students Experiences and Perspectives about PocketLab Interactive Mobile Technology

The attitudinal survey results revealed that students in both groups had comparable perspectives about the instructional approach used to learn physics. Students in both groups found the instructional approach used to learn physics beneficial for their learning (Table 3). For example, control and treatment groups agreed that their lab experience was beneficial when learning physics, with 88 % of participants agreeing in the treatment group and 87% in the control group. Similarly, both groups believed that the approach that they experienced supported their learning of physics concepts, with 88 % agreeing in the control group and 83 % agreeing in the treatment group. Both groups tended to agree that the learning experience was enjoyable, with students who experienced Vernier technology tending to have less favorable perspectives (68 % agreed) about their experience compared to students who participated in the PocketLab type of instruction (7 % agreed).

Regarding motivation to learn physics using an approach they experienced, although both groups tended to agree, the percentages were lower than for other items, with 62 % agreeing in the control group and 57 % in the treatment group. Ninety-three (93 %) percent of students who experienced PocketLab instruction believed it allowed for flexibility. In contrast, only 56 % of students who participated in laboratory instruction that used Vernier technology (control group) believed it allowed for flexibility. Similarly, most students (93 %) in the treatment group indicated that the PocketLab instruction allowed them to connect physics concepts to the real world. In comparison, 71 % of students in the control group supported this statement. The PocketLab provided more flexibility towards the experimental setup students chose to work with and enhanced personalized experience by moving away from ideal-case scenarios that tied closely to the theoretical aspect of the course.

Although both groups tended to describe their experiences as positive, a vast majority of students (90 %) who experienced Pocket Lab instruction agreed that their experience was positive versus 71 % of students who participated in the instruction that utilized Vernier technology. After experiencing instruction via respected approaches, 67 % of students who experienced the PocketLab approach indicated that they would recommend using it in the future versus only 32 % of students in the control group who indicated that they would recommend it. Interestingly, more students (88 %) in the control group who did not experience PocketLab mobile technology-enhanced instruction preferred to utilize more mobile technology to conduct experiments versus 70 % of students in the PocketLab classroom who experienced mobile technology to conduct experiments. Both groups preferred instruction that used mobile technology to conduct experiments in the physics laboratory if given an option, with 85 % of students in the control group and 77 % in the treatment group indicating a preference for mobile technology.

Table 3
Students' Experience in the Laboratory Classroom

Survey Item	Control Group %	Treatment Group %
1. The lab experience allowed for flexibility	56	93
2. During the lab experience, I was able to connect physics concepts to the real world	71	93

3. I would describe my experience with physics lab as positive	71	90
4. The lab experience was beneficial for me to learn physics	88	87
2. The lab experience supported my learning of physics concepts	88	83
6. The lab experience was enjoyable	68	77
7. I would prefer for physics lab to utilize more mobile technology to conduct experiments	88	70
8. I would recommend using the same approach to teach physics laboratory classes in the future.	32	67
9. The lab experience motivated me to learn physics	62	57

While using a t-test to determine statistically significant differences between the two groups was justified by the number of participants in the study, the distribution of responses for some of the items did not resemble that expected from a normal distribution. As a result, a Mann-Whitney U test was conducted on each item to determine whether there was a statistically significant difference in the mean rank between the group that experienced the Vernier technology approach and the group that experienced the PocketLab technology. The group using the PocketLab (Mdn = 2) experienced a greater degree of flexibility in comparison with the group using Vernier technology (Mdn = 2), U = 319 p = .001. This result could be attributed to the versatility and multisensory capabilities offered by PocketLab technology that allowed for a variety of experiments that could be performed outside the laboratory classroom. A significant difference between groups was observed when evaluating participants' ability to connect concepts to the real world. The test shows that the treatment group (Mdn = 2) could make better connections to the real world when applying physics concepts than the control group (Mdn = 2), U = 392 p = .019. A significant difference was observed between the groups regarding using the same approach to teach the lab in the future. The treatment group (Mdn = 2) had a stronger preference to adopt the PocketLab laboratory instruction when compared to the control group (Mdn = 3), U = 310, p = .003

The qualitative data analysis was conducted to explain the results of the quantitative analysis further and offer insights into the students' perspectives and experiences. The open coding process was employed to analyze the qualitative data (Strauss and Corbin, 1998). Open codes were identified and subsequently grouped into broader themes. This approach allowed to identify the overarching patterns in the data. Table 4 provides examples of these open codes and corresponding excerpts from the students' responses during the qualitative data analysis.

Table 4

An Example of Open Codes in the Study

Open Code	Definition	Examples of students' words
Real-world application	Instances where students mention how PocketLab helps to apply physics concepts to real-life situations	• *Apply physics to everyday situations"* • *"Use collected data living life day to day"* • *"Connect physics with everyday lives"* • *"Helps relate the lab to the real world"* • *"Allows us to use our body movements and calculate how we move and how physics is applied to us in the real world"*

		• *"A way to understand physics better and be able to relate it more to real-life applications"* • *"It allows me to further understand physics concepts in the real world and allows me to see connections between the two"* • *"We are able to make the world our lab and use anything out in life as an experiment to see the real-world applications"*
Flexibility	Instances where students mention the flexibility that PocketLab offers	• *"There is more flexibility and freedom to choose what to experiment with in PocketLab"* • *"The benefit of the PocketLab would be the freedom it provides"* • *"You are not tied to one location"* • *"Using mobile technology with its flexibility makes physics more accessible to people"* • *"There are so many possibilities"* • *"PocketLab is more mobile and allows a wider possibility of experiments"* • *"More freedom, more portability and more versatility"*

After qualitative data was coded, four qualitative themes emerged: *Enhanced Understanding of Science Concepts, Experiencing Real-Life Learning, Engaging in Learning by Doing,* and *Limitless Possibilities.* Students discussed how PocketLab instruction improved their understanding of the material and facilitated retention. Participants described the real-life and real-world experiences they could participate in while engaging with interactive mobile PocketLab technology. In addition, students indicated that PocketLab allowed them flexibility, versatility, and efficiency.

Enhanced Understanding of Science Concepts

In this theme, students discussed how they better understood physics concepts by engaging with PocketLab technology. For example, a student stated: *"I prefer to use the mobile technology because it allows for easier data collection. It is easier to understand the data when it is being collected on your phone and can be quickly graphed".* The fellow students agreed and explained that they understood topics better and felt that learning with PocketLab was "easier" and *"a great way to comprehend the material"* as *"PocketLab forces you to learn the concepts."* Students explained that visual aspects offered by PocketLab were essential for improved understanding and elaborated that strong understanding facilitated retention of the information: *"PocketLab helped to learn and retain information because it provided better visuals."* Students discussed other aspects and features of PocketLab that helped to enhance their understanding: *".... mobile technology could be a way to understand physics better and be able to relate it more to real-life applications because we are the ones collecting data through movement and equipment".* Students indicated that engaging with PocketLab technology gave them a deeper understanding and allowed them to make connections: *"...it allows me to further understand physics concepts* *in the real world and allows me to see connections between the two."* Improved understanding and retention of the material were important characteristics that added to students' favorable perspectives toward PocketLab instruction.

Experiencing Real-Life Learning

Students discussed how PocketLab allowed them to experience real-world learning. Participants emphasized how being engaged with PocketLab connected ideas and learning to the real world and real life. PocketLab made it easier to relate to learning and, therefore, was more motivating for students. Terms such as *"real life," "real-life situations," "real world," "real world connections*," *"real-world scenarios*," *"real data,"* and *"relatable"* were frequently mentioned by students in their responses describing their experience with PocketLab technology. For example, a student mentioned: *"It helps relate the lab to the real world more and allows you to go outside and conduct your experiments."* Students enjoyed using "real-world objects" while learning physics with PocketLab*: "PocketLab is more mobile and allows a wider possibility of experiments involving real-world objects."* One student elaborated on how mobile technology such as PocketLab transformed the world into a lab: *"Traditional lab is limited to whatever we can do in the lab, but with the other technology like PocketLab, we are able to make the world our lab and use anything out in life as an experiment to see the real-world applications and how it moves in relation to physics. This allows to accommodate students' learning styles and allows students to flourish in the classroom to understand and gauge their learning".* Students stated that with mobile technology such as PocketLab, they could *"see physics in action," "go outside the lab," "see real-world connections," "apply physics to everyday situations," "use collected data living life day to day,"* and *"connect physics with everyday lives."* This, in turn, helped students learn physics more in-depth, understand projects better, and make remembering and retaining information easier since the learning experience was more memorable and motivating.

Engaging in Learning by Doing

The third theme emphasized the hands-on learning facilitated by PocketLab interactive mobile technology. Students discussed opportunities for hands-on, engaging, interactive, and exciting activities that PocketLab provided. They also shared that PocketLab made learning experiences more enjoyable and more memorable. One student commented: *"You are watching it happen and can see the results,"* and another agreed: *"You can visually see differences in these subjects."* These features of PocketLab technology made students' experience more engaging: *"It is more engaging and less restrictive."* Participants explained why participating in PocketLab laboratory instruction was more engaging than participating in a traditional science lab*: "Mobile technology would be more helpful to people who learn by doing things or manipulating things and would help people become more invested in the results of the experiments because the results would be personal."* Another student supported the idea: *"Mobile technology could be more beneficial than the traditional one because students would be more willing to engage and really see and experiment firsthand."* Students explained and gave examples of how PocketLab instruction engages them in learning*: "PocketLab is amazing and an engaging way for us to learn about physics and how we move in a real-life application standpoint. This technology allows us to use our body movements and calculate how we move and how physics is applied to us in the real* *world"*. Students provided multiple examples of the hands-on opportunities and experiences offered by PocketLab, expressing strong support for learning physics using this technology.

Limitless Possibilities

In the fourth theme, students discussed flexibility, versatility, efficiency, and ease of use provided by interactive experience with PocketLab in the classroom. Students emphasized many possibilities that PocketLab offered. For example, a student commented: *"There is more flexibility and freedom to choose what to experiment with in PocketLab."* The other students echoed by stating that *"there are so many possibilities," "more freedom," "more portability,"* and *"more versatility."* One student explained: *"The benefit of the PocketLab would be the freedom it provides and the ease of use since no wires are required, and you are not tied to one location. PocketLab can be used for many more experiments than traditional equipment…"*. Students argued that flexibility and versatility made physics more accessible to learners: *"Using mobile technology with its flexibility makes physics more accessible to people."* Ease of use was another characteristic of PocketLab that students discussed. Thus, a student explained: *"It is easier to see and collect the data with the PocketLab. It also allows for more freedom in the experiments"*. The ease of use enabled students to broaden their possibilities and opportunities for learning physics.

Discussion

Combining insights from quantitative and qualitative data informed the use of PocketLab interactive mobile technology in an undergraduate science laboratory classroom. It provided a comprehensive understanding of the impact of PocketLab, thereby informing its use in such settings. Quantitative data was instrumental in assessing students' learning outcomes and combining quantitative and qualitative data offered insights into students' perspectives and experiences.

Quantitative analysis revealed that while students who experienced traditional instruction with Vernier technology outperformed students in the PocketLab treatment group in the overall summative assessment of science concepts taught in the class, upon further examination, it was determined that the difference was statistically significant only for problem-solving types of questions. There was no statistically significant difference in students' summative assessment scores for the definition and conceptual kinds of questions. The difference in performance on the problem-solving questions was likely attributed to students' familiarity with the problem-solving approaches required for Vernier technology experiments, which closely matched those discussed in lectures. Additionally, the experimental setup used with Vernier technology had configurations similar to those addressed during lectures. If the summative assessment results reflect the impact the technology had on students' performance, it poses the question of how the technology played a role in the learning process. It can be speculated that minimizing non-idealities (friction, air resistance, etc.) in the setup of experiments and resembling the setup geometry with textbook problems in the control group might have contributed to this result. Exploring students' perspectives and experiences with PocketLab interactive mobile technology involved combining quantitative survey responses and qualitative feedback. This analysis revealed some valuable insights. Students who experienced PocketLab instruction had stronger favorable perspectives and positive experiences than students who experienced the traditional Vernier technology. Students noted that the flexibility and ability of the PocketLab to connect science concepts to real-world ideas and phenomena were significant advantages over Vernier technology. In addition, students who experienced PocketLab interactive technology in the classroom expressed higher satisfaction with their learning experiences and demonstrated a greater likelihood of recommending this type of instruction in the future than students in the control group.

Table 5 shows the convergence of quantitative and qualitative data regarding students' perspectives and experiences with PocketLab interactive mobile technology in the classroom. Convergent mixed methods design aims "to obtain different but complementary data on the same topic" (Morse, 1991, p. 122) to better understand the research problem. To demonstrate how the data complement each other, Table 5 presents mean scores from quantitative Likert scale survey items alongside corresponding qualitative themes illustrated with examples of participants' quotes. For example, students generally agreed with the quantitative survey item *During the lab experience, I was able to connect physics concepts to the real world* (M=4.30). This quantitative finding was reinforced by qualitative data under the theme, *Experiencing Real-Life Learning*, with a student quote to illustrate this connection better. Qualitative data offered more depth and context to complement the quantitative survey findings.

Table 5

Merged Quantitative and Qualitative Data for Students in a Treatment Group

Survey Item(QUAN)	Mean	Theme (QUAL)	Example of Students' Quotes
1. The lab experience was beneficial for me to learn physics.	3.97	• Enhanced Understanding of Science Concepts • Engaging in Learning by Doing	*"Mobile technology could be more beneficial than the traditional one because students would be more willing to engage and really see and experiment firsthand."*
2. The lab experience supported my learning of physics concepts.	3.97	• Limitless Possibilities • Experiencing Real-Life Learning • Engaging in Learning by Doing • Enhanced Understanding of Science Concepts	*"…it allows me to further understand physics concepts in the real world and allows me to see connections between the two."*

3. The lab experience was enjoyable.	3.97	• Engaging in Learning by Doing	*"Mobile technology could be more beneficial than the traditional one because students would be more willing to engage and really see and experiment firsthand."*
4. The lab experience motivated me to learn physics.	3.63	• Engaging in Learning by Doing. • Experiencing Real-Life Learning	*"Mobile technology would be more helpful to people who learn by doing things or manipulating things and would help people become more invested in the results of the experiments because the results would be personal."*
5. The lab experience allowed for flexibility.	4.33	• Limitless Possibilities	*"The benefit of the PocketLab would be the freedom it provides and the ease of use since no wires are required, and you are not tied to one location. PocketLab can be used for many more experiments than traditional equipment…".*
6. During the lab experience, I was able to connect physics concepts to the real world.	4.30	• Experiencing Real-Life Learning	*"Traditional lab is limited to whatever we can do in the lab, but with the other technology like PocketLab, we are able to make the world our lab and use anything out in life as an experiment to see the real-world applications and how it moves in relation to physics…."*
7. I would describe my experience with physics lab as positive.	4.13	• Enhanced Understanding of Science Concepts • Experiencing Real-Life Learning • Engaging in Learning by Doing Limitless Possibilities	*"PocketLab is amazing and an engaging way for us to learn about physics and how we move in a real-life application standpoint. This technology allows us to use our body movements and calculate how we move and how physics is applied to us in the real world".*

Note. Likert scale survey response format was 1= *Strongly disagree*, 2=*Disagree*, 3=Neutral, 4=*Agree*, 5= *Strongly agree*

The treatment group benefited from the flexibility offered by the PocketaLab approach. Similar to previous scholarship on the topic, the current study confirmed favorable perspectives and experiences that students had regarding PocketLab in a science laboratory (Fuchsova & Korenova, 2019; Gomez-Espina et al., 2019; Loperz-Moranchel et al., 2021; Reyna, 2021; Serpagli & Mensah, 2021; Teri el al., 2014; Vieyra et al., 2019). Students described their experiences with PocketLab technology as positive and emphasized that it helped them relate science concepts to the real world they experienced daily. PocketLab improved understanding of the material, reinforced deeper learning, and provided hands-on, engaging experiences. Students indicated increased interest in subject matter, motivation, and enhanced learning experience consistent with results reported in the literature (Bayar & Kurt, 2021; Ekin et al., 2020; Lopez-Moranchel et al., 2021; Zhai et al., 2019).

Conclusions

This study aimed to evaluate the effect of PocketLab interactive mobile technology on content knowledge acquisition and to understand students' experiences and perspectives regarding its use in an undergraduate algebra-based physics laboratory classroom. Additionally, the study explored how integrating quantitative and qualitative data can inform the application of PocketLab technology in undergraduate science laboratory settings. Integrating quantitative and qualitative data provided a comprehensive understanding of the impact of PocketLab on students' learning. Quantitative data assessed learning outcomes, while qualitative data offered insights into students' perspectives and experiences. This integrative approach validated the findings and underscored the practical aspects of PocketLab technology in the science classroom.

The study highlighted that while Vernier technology may offer advantages for problem-solving questions, the flexibility and real-world application of PocketLab interactive mobile technology enhance students' learning experience. Students' positive feedback and increased engagement with PocketLab reveal its potential to improve understanding and foster deeper learning while contributing to a more effective and enjoyable learning experience in science laboratory classrooms.

The findings of this study align with existing research on the impact and benefits of interactive mobile technologies in science education. Previous studies have highlighted that various such technologies can positively affect students learning in a science classroom. This research showed that interactive mobile technology implemented in this study had similar benefits for students.

Recommendations and Limitations

Based on the study's results, it is recommended that a hybrid instructional approach should be implemented, and educators should be encouraged to consider integrating both PocketLab interactive mobile technology and traditional methods in their instruction, harnessing the advantages of each to optimize student learning outcomes. Based on the study's findings, it is recommended to integrate hands-on interactive mobile technologies into the science classroom if available and logically possible.

The authors recognize the limitations associated with the self-reported survey data presented in this study, which can seldom be independently verified and can be subject to social desirability bias and exaggeration.

Implications and Future Research

This study holds implications for higher education faculty and K-12 teachers considering the adoption of PocketLab interactive mobile technology or similar platforms. The insights provided valuable information on students' learning, experiences, and perspectives with such technologies. The positive aspects underscore the potential benefits of incorporating PocketLab into science education settings, emphasizing the importance of balancing technological innovation with traditional methods for optimal learning outcomes.

To further advance the understanding of the impact of the PocketLab interactive mobile technology, future research should involve a larger participant pool, encompassing multiple classrooms and diverse science disciplines. It will be beneficial to conduct longitudinal studies spanning multiple semesters, providing insights into the sustained effects of PocketLab technology on students' achievement scores. Additionally, exploring the influence of students' pre-existing attitudes toward science and physics, particularly on their performance, could contribute to a more nuanced understanding of the results. Future research should investigate whether PocketLab enhances student motivation and persistence and impacts academic retention and success.

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Statements and Declarations

Ethical statement. Approval was obtained from the ethics committee of Aurora University. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

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