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Development and evaluation of mobile learning application for practical chemistry among pre-service teachers

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Abstract
Lack of proper laboratories and inadequate facilities have become some of the factors affecting chemistry practical in Nigeria which therefore affects students' performance. While there were many studies conducted on the effectiveness of mobile learning, literature remains very scarce in the Nigerian context. In order to tackle this problem, using Analysis, Design, Develop, Implementation and Evaluation (ADDIE) instructional design model, the researchers developed and tested the effectiveness of mobile learning towards improving college of education pre-service teachers' achievement in practical chemistry. The study adopted the use of repeated measures design whereby 50 pre-service teachers were purposively used in the study. A 40-item Practical Chemistry Achievement Test (PCAT) which was subjected to expert validation and reliability test was used to obtain data for the study. A normality test was conducted using Kolmogorov–Smirnov test and it was revealed that the data were normally distributed ($P > 0.05$). The students were given two pre-test and post-measures before and after the 8-week treatment period. The data were analyzed using mixed design repeated measures analysis of variance and we found that students' performance improved periodically with each testing period ($F_{(3,147)} = 109.475$, $P = 0.000$ with an effect size of (ηp^2) = 0.916) after the treatment. The finding also revealed no significant differences in the performance of the students on the basis of gender that ($F_{(3,144)} = 2.051$, $P = 0.109$) with an effect size of (ηp^2) 0.21. This finding has some implications for lecturers, researchers and policy experts on the need to incorporate mobile learning in education. This finding provides insights on the effectiveness of mobile learning towards enhancing students' chemistry practical knowledge.

Keywords Mobile learning · Chemistry practical · Educational technology · Pre-service teachers · ADDIE model · ICT in education · Chemistry education

1 Introduction

1.1 Problem statement and study background

Chemistry practical is an essential part of science education that offers students a hands-on approach to learning and understanding of complex chemical concepts and processes. This practical component is regarded as a core determinant of mastery in chemistry [34, 45]. When students learn through practical activities, especially in chemistry, they tend to understand concepts better [1, 52].

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However, in Nigeria, the inadequacy of infrastructure and equipment reduces the effectiveness of chemistry practical sessions. Without proper laboratory facilities and essential equipment, students cannot engage in hands-on experiments thereby limiting their understanding of chemical principles and their ability to apply them in real-world contexts. Additionally, documented evidence [9] revealed that practical chemistry in Nigeria faces several difficulties affecting the effectiveness and quality of chemistry education. Similarly, some studies have reported that practical chemistry in Nigeria faces serious challenges due to lack of adequate laboratory and basic infrastructure to facilitate smooth practical session which affects students' performance [19, 33]. Ideally, practical sessions in chemistry should provide students with opportunities to engage in experiments that reinforce theoretical knowledge.

Nonetheless, effective chemistry practical requires well-equipped laboratories, access to various chemicals and reagents, and sufficient safety measures to ensure a conducive learning environment. Nonetheless, over the years, the absence of laboratory equipment and infrastructure has limited the scope of experiments and practical demonstrations thereby affecting students' performance in chemistry. In the Nigerian context, many studies [32, 45, 49, 58] have noted that lack of sufficient laboratory facilities and infrastructure significantly hinders the practical aspect of teacher training. This leads to deficiencies in essential practical skills which adversely affect students' academic performance. Moreover, while existing studies conducted outside Nigeria [2–4, 14, 18, 27, 30, 35, 59] revealed the effectiveness of mobile learning on students' achievement, however, very few studies [22, 42, 43, 50] have been conducted in Nigeria to enhance students' performance and these studies were not focused on chemistry practical. In order to address lack of proper laboratories and inadequate facilities and equipment affecting chemistry practical in Nigeria, the researchers developed and evaluated a mobile application to enhance pre-service teachers' performance in practical chemistry among colleges of education in Nigeria. This study will provide some insights on the effectiveness of mobile learning towards enhancing students' performance in practical chemistry.

Çalışır et al. [8] stated that mobile learning is a type of distance education in which students use mobile devices for learning considering their convenience and comfort. One of the main benefits of mobile learning is that it allows learners to access materials on the go, which is particularly useful for busy learners who may not have time to sit down on a computer [2]. The integration of technology in modern classroom environments has become a trend due to the constant emergence of various studies in different forms [10, 20, 21, 39] seeking to incorporate technology in teaching and learning. More importantly, learning with the help of technology fosters creativity and empowers learners to be autonomous [2]. Through the use of modern technology in education, educators can easily provide lessons in different forms where both learners and tutors are separated from the walls of the classrooms [44].

According to Talan [56], mobile devices are now a major element during classroom instructional processes. The advent of mobile devices has changed our ways of learning, and with high-speed processors and internet, mobile devices have become the desired choice in education. Mobile learning is vital for teaching and learning as it facilitates learning through features such as easy usability [36], portability [26], ubiquity [60], ensuring ease of learning [43, 54], cost-effectiveness [34], improving communication and social interaction [Park et al., 2012), providing continuous personalized learning and improving communication [12], exclusion of spatial and temporal limitations [5], facilitating collaborative learning [37], fostering autonomous learning [17], seamless connectivity [31], mobility [51], and blended learning [6].

Furthermore, mobile learning has been utilized to provide access to educational resources and interactive learning materials through mobile applications or platforms like digital textbooks, educational videos, simulations, and interactive quizzes. This allows students in remote areas or with limited access to traditional educational resources to learn at their own pace and convenience. The use of mobile devices for educational purposes can support and improve the learning process anytime, anywhere, and mobile learning is an emerging aspect of educational technology at different levels of education [48]. Mobile learning application enables learning anytime and anywhere. It is instantly accessible, helping to fuel curiosity, collaborate with others, and enrich experiences [47, 61].

The use of mobile learning application has the potential to overcome challenges faced by the traditional education system in Nigeria, such as insufficient educational resources, inadequate infrastructure, and limited access to qualified teachers [55]. These applications provide students with access to a wide range of educational materials, including video lectures, podcasts, e-books, and interactive learning tools, regardless of their location. Furthermore, mobile learning facilitates self-regulated learning, creates collaborative learning environments [38], and helps students improve their technical skills [37]. Thus, in light of the preceding discussions, this study aims to provide insights into the potential of mobile learning to enhance pre-service teachers' performance in practical chemistry in Nigeria.

1.2 Empirical review and hypothesis development

1.2.1 Mobile learning and students' achievement

There are many studies conducted in the field of mobile learning as they enhance students' achievement. For example, Kouhi and Rahmani [35] designed and developed a mobile application for teaching triple multiplication to young pre-school students and the finding revealed that students' achievement improved significantly after exposure to mobile learning app. Mohammed et al. [42] developed an educational game to teach educational technology postgraduate students during the COVID-19 pandemic and findings revealed that students' performance significantly increased after exposure to mobile educational game to a very large extent. Demir and Akpinar [14] studied the effect of mobile learning technology on undergraduate students' achievement in graphic education and the findings revealed that the use of mobile application significantly improved the achievement of students. Han et al. [27] designed and tested the effectiveness of an artificial intelligence mobile chatbot on college of nursing students' performance and the findings revealed that the use of artificial intelligence mobile chatbot improved the performance of students. Amasha et al. [4] developed a java-based mobile application to teach primary school mathematics students and findings revealed that mobile application enhanced students' performance. Hsu et al. [30] designed and tested the effectiveness of an expert-decision-making mobile application to teach college students climate concepts and their findings revealed that students' performance significantly improved after exposure to the mobile application. Oyelere et al. [50] designed, developed and evaluated a mobile application for teaching of computing education and the findings revealed the adoption of mobile application improved students' performance. Vazquez-Cano et al. [59] designed and tested the effectiveness of mobile chatbot towards improving undergraduate students' punctuation skills and their findings revealed that students' punctuation skills significantly improved after exposure to artificial intelligence mobile learning. Ali et al. [2] developed a mobile application for teaching undergraduate English language and the findings revealed that the performance of students improved significantly after exposure to mobile application. Essel et al. [18] designed and tested the effectiveness of a mobile virtual assistant on undergraduate students' programming skills and their findings revealed students' performance improved significantly. Mohammed et al. (44) tested the effectiveness of students' performance in a microteaching course using Telegram and WhatsApp mobile applications and the findings revealed that students' achievement improved significantly after exposure to instruction using mobile learning. Falode et al. [22] designed and evaluated a mobile application on educational technology students' achievement and the findings revealed that the adoption of mobile application in teaching and learning of educational technology significantly improved students' performance. Alkhateeb and Al-Duwairi [3] designed and tested the effectiveness of mobile application to teach geometry concepts to undergraduate students and their study revealed that students' performance increased significantly after exposure to mobile learning.

The foregoing discussions revealed the usefulness of mobile learning towards enhancing students' performance in various disciplines. The studies we reviewed focused on educational technology [14, 22, 42], micro-teaching [43], programming and computing [18, 50], English and punctuation skills [2, 59], nursing [27], mathematics [3, 4, 35], and climate change concepts [30]. While the preceding studies revealed a unanimous finding in terms of the effectiveness of mobile learning towards enhancing students' performance in different fields, however, the studies reviewed were not conducted on Chemistry practical which therefore leaves a gap that needs to be filled. As a result, there is need for more studies to be conducted to close these gaps.

In view of the preceding discussion, we formed the following hypothesis:

Ho_1: There is no significant difference in the mean achievement scores of pre-service teachers taught practical chemistry before and after exposure to mobile learning application.

1.2.2 Mobile learning and gender differences in students' achievement

Gender as a moderating variable continues to play a role in terms of students' performance in mobile learning technology. For example, Hilao and Wichadee [29] checked whether there is any significant difference in male and female students' performance after exposure to mobile learning and the findings revealed that the students did not differ in their performance based on gender. The study of Falode et al. [22] revealed that there was a significant difference in the achievement of male and female educational technology students exposed to mobile learning in favour of female students. The study of Daud et al. [13] revealed a significant difference in the achievement of male and female students exposed to mobile learning. Additionally, the study of Essel et al. [18] found no significant difference in the achievement

of male and female students after using mobile chatbot for instruction. Mohammed et al. [41] checked gender difference in students' microteaching performance in a mobile learning using Telegram and WhatsApp and the findings revealed there was no significant difference in the achievement of male and female students.

In line with the above studies reviewed, there seems to be no unanimous agreement regarding the role of gender in terms of students' performance during a mobile learning strategy. From the studies reviewed above, there are contradictory findings. For example, while some studies [13, 22] found a significant difference in students' performance based on gender, some of the studies [18, 29] found no significant difference in terms of students' performance in a mobile learning. Therefore, this creates another gap that needs to be filled in order to add more literature in terms of gender differences in mobile learning.

Thus, in view of this development above, we formed the next hypothesis:

Ho_2: There is no significant difference in the mean achievement scores of male and female pre-service teachers taught practical chemistry before and after exposure to mobile learning application.

1.3 Methodology

The study adopted a repeated measures design to evaluate the effectiveness of the mobile learning application whereby one group of pre-service students where studied over a period of 8 weeks in order to ascertain the periodic improvement in their achievement as a direct influence of the treatment. The use of this type of design enables researchers to assign the same participants into different treatment groups with the aim of studying the periodic improvement in their performance over a long period of time. In this study, the same participants were studied over a period of 8 weeks in order to study changes in their performance. Edmonds and Kennedy [16] observed that repeated measures design permits researchers to acquire different data points over a long period with the main purpose of checking the observed variation in performance as a result of treatment or time. In this type of design, the various test conditions serve as a control for the different treatment settings, thus enabling the easy control of some extraneous variables [42]. Additionally, in order to control for extraneous variables by eliminating hawthorn effect, research assistants were trained and used in the study. As a result, in this design, we subjected the participants to different testing conditions before and after the treatment over a long period of time to measure their periodic improvement in performance as a result of the mobile learning treatment issued to them. This design has been used in various studies [40, 42].

1.4 Participants

Purposive sampling technique was used to select 50 year-two pre-service teachers from Federal College of Education (FCE) Kontagora, Niger State Nigeria for the 2023/2024 academic session out of a total number of 757 pre-service teachers' population. The choice of the institution was selected due to the fact that it is a mixed school, and also due to the availability of ICT infrastructure. The choice of year two pre-service teachers was employed because the course contents covered during the treatment (balancing of redox reaction, redox titrations, and measurement of pH using indicators) were domiciled in year two chemistry curriculum.

1.5 Instrument

The research instrument used in this study was the Practical Chemistry Achievement Test (PCAT) which consisted of 40-item multiple-choice questions drawn using Benjamin Bloom's table of specification. Bloom's table of specification was used in order to spread the entire questions across the various sub-levels of the cognitive domain of education as specified by Bloom. The test items thus covered the areas of knowledge, comprehension, application, analysis, synthesis and evaluation in order to thoroughly measure the students' cognitive understanding at the end of the treatment using mobile application. As a result, the questions were drafted to fill each of the cognitive domain areas provided by bloom. The instrument had two sections: section A and section B. Section A deals with the students' demographic data while section B consists of the 40-item multiple choice questions with options A-D, containing one correct answer and three distracters. In order to ascertain the item difficulty index of the test, we conducted an item analysis where a P-value of 0.36 was obtained, thus falling in accordance with the acceptable average difficulty range criteria of 0.30 to 0.49 [28]. As a scoring criterion, each correct answer was scored 1 mark while an incorrect answer was scored 0. This therefore means that the maximum score obtainable from the test was 40, while the minimum score was 0.

1.6 Validity and reliability of instrument

The instrument validation was done in two phases. First, we subjected the PCAT to expert validation in order to determine its validity by giving it to experts in the field of chemistry education and measurement and evaluation. These experts checked the face and content validity of the instrument and provided useful insights in the final draft of the instrument. Their corrections in terms of lengths of questions, eliminating easy options, chronological arrangement and language clarity were then implemented in the final production of the instrument used in the study. As for the mobile learning application, we first created a prototype that was given to experts in the field of instructional design, educational technology, computer science and software engineering in order the check the user interphase, selection pane, colour contrast and user friendliness during operation. Their observations were then corrected and the final mobile application was finally produced. In order to ascertain the reliability of the PCAT, copies of the instrument were given to 20 different set of students that were within the population but outside the sample in a single administration and a reliability figure of 0.79 was obtained using Kuder-Richardson 20 formula. The use of Kuder-Richardson 20 formula enables researchers to check the internal consistency of the items which tells whether the instrument, based on the reliability index obtained, is reliable or not [52]. During the pilot test, some of the test items returned with a very weak value and were therefore removed in the final copy of the instrument to be used for the study. The weak test items were removed due to their weak reliability index in order not to affect the validity and reliability of the entire result [15].

1.7 Development of mobile learning application

The mobile application used in this study was designed using the ADDIE instructional design model as stated below:

1.8 Analysis

The analysis phase in developing the chemistry practical mobile learning application involves a comprehensive examination of need assessment and student profiling. The need assessment involves engaging with educators and students to identify challenges in chemistry practical. This includes evaluating existing materials such as textbooks, lab manuals, and online resources to streamline the course development process. By focusing on learners' needs and the learning context, the analysis phase ensures the effective utilization of available resources and sets the foundation for the subsequent stages of course design and implementation.

1.9 Design

During the design phase of the chemistry practical mobile learning application, we created a seamless and effective user experience through careful user interface (UI) design, a well-structured content layout, and the development of a functional prototype. A computer programmer and one of the researchers were involved in designing the package. The UI design includes selecting appropriate colors, typography, and icons that align with the subject while maintaining a consistent and visually appealing look. Ease of navigation is prioritized by ensuring users can easily access sections such as theory, experiments, quizzes, and supplementary resources. Choices regarding the programming language, operating system (Android), and memory size were made. Multimedia elements like videos and images are strategically embedded to enhance comprehension. Practice exercises and quizzes are integrated into relevant lessons to promote active learning.

Thus, in view of the foregoing, the screenshot of the mobile learning application interphase is hereby presented in Fig. 1 below.

1.10 Development

In the development phase, the chemistry practical course content involves creating comprehensive instructional materials, organizing lesson sequences, and constructing relevant assessments to enhance learning outcomes. This phase considers factors such as the progression of difficulty, logical flow of concepts, and resource efficiency. Both formative assessments for ongoing feedback and summative assessments for final evaluation were formulated. The mobile application was developed using Kodular, a no-code platform for Android applications. Learning content, assessments, and YouTube video links were managed via an e-learning platform built with JavaScript, HTML, CSS,



Fig. 1 Screenshot of the mobile application interphase

and PHP. User authentication protocols were integrated to validate identities during login and interactions. Authentication and authorization mechanisms were implemented to protect content and manage access securely. User registration and login functionalities were designed with advanced security measures. Self-assessment exercises were incorporated in each unit to gauge cognitive levels. Data integration was employed to ensure efficient communication between the app's front-end and back-end systems, with a robust database architecture established to store user profiles and track progress. An API was developed to facilitate seamless data exchange, maintaining consistency of user information and progress across devices.

1.11 Implementation

We trained research assistants that helped the various students to install the mobile learning application. The research assistants were trained on the smooth operation of the application. They were trained to help the students install and operate the mobile application without difficulties. Additionally, an orientation session was conducted to familiarize students with the application's usage. The orientation was conducted in a day and it served as an avenue to make the students to familiarize themselves with the application. Thereafter, the students went on to use the platform to learn the various concepts after successful installation of the mobile app.

1.12 Evaluation

The evaluation phase of a chemistry practical course includes a post-test administered after the course, which was designed to assess their comprehension of practical chemistry topics taught with the application.

1.13 Experimental procedure

The study involved the use of human subject and it was conducted in accordance with the national code of research ethics in Nigeria [23]. The students were also assured of the confidentiality of their data for research purpose only. Additionally, the students signed a consent form permitting the conduct of this study where they were informed that the outcome of the study would be published in a research journal. The researchers issued two separate pre-test measures (pre-test 1 and pre-test 2) within a two-week interval prior to the commencement of the study in order to measure the students' entry behavior. Thereafter, the students were subjected to the treatment using the mobile learning application over a period of 8 weeks. The students interacted with the mobile application to learn the various chemistry practical concepts. For every week, the teacher introduced the concepts to be studied by the students where they learnt at their own pace once every week. The students planned their learning process in an individualized learning with the teacher serving as facilitator. The contents covered were balancing of redox reaction, redox titrations, and measurement of pH using indicators. After the 8-week treatment period, the researchers then administered the posttest measures (posttest 1 and posttest 2) within a period of two weeks. All other sources of information were blocked during the treatment to make sure the students concentrated and that the data came from the mobile application only. In collaboration with the programmers and ICT experts in the school, all other sites that could provide useful information to the students during the treatment were blocked. The mobile application was programmed in a way that any student that leaves the app for a while will be automatically logged out. As a result, the students were restricted to only data from the mobile application. During each test period, the students were required to provide answers within one hour.

1.14 Method of analysis

The various results we obtained during the experiment were subjected to analysis using a mixed design repeated measures analysis of variance (RM-ANOVA) in order to compute the within subject effect of the various test conditions. RM-ANOVA was used in this study because the researchers want to check the within-subject effect of a given treatment when the same participants are subjected to different test occasions over a long period of observation or treatment in order to determine the periodic differences in their performance [40]. We also computed the descriptive statistics using mean and standard deviation. Additionally, we conducted a normality test using Kolmogorov–Smirnov test and the result revealed that the data was normally distributed ($P > 0.05$). Furthermore, the Skewness and Kurtosis of the data falls within the acceptable range of ± 2 and ± 7 for Skewness and Kurtosis respectively [7, 24, 25] which therefore warrants the use of parametric statistics. In order to ensure that the assumption of sphericity was not violated as one of the basic assumptions of RM-ANOVA, we computed the Mauchly's test of sphericity and the value revealed that $P > 0.05$ which means that the variance of all the within subject pairings of the different test conditions is equal. Sidak post-hoc test was also conducted to show the direction of the significant differences. The result was computed using SPSS software version 25.

2 Result

Table 1 revealed the mean and standard deviation of students' achievement scores at different test period. The table revealed the students had $M = 47.02$, $SD = 10.23$, and $M = 48.34$, $SD = 10.76$ at pre-test 1 and pre-test 2 respectively. The table also revealed that the student obtained $M = 66.63$, $SD = 9.01$, and $M = 74.68$, $SD = 9.19$ at posttest1 and posttest 2 respectively. This reveals that the students' performance periodically improved in each case as a result of the treatment effect. Additionally, the graphical illustration of the pretest and posttest scores of the students' performance at different test occasions is hereby presented in Fig. 2.

Table 2 revealed the Kolmogorov–Smirnov normality test conducted to determine whether the data was normally distributed. The table revealed that $P > 0.05$ for all the different four test occasions. Therefore, the hypothetical assumption that the data set came from a normal distribution to warrant the use of parametric inferential statistics is hereby confirmed.

Table 3 revealed the performance of male and female students at different test occasions after exposure to mobile learning application. The students had $M = 48.32$, $SD = 10.47$ and $M = 44.89$, $SD = 9.71$ at pre-test 1 for male and female

Table 1 Mean and standard deviation of students' achievement scores at different test occasions

Test	N	Mean	SD
Pretest 1	50	47.02	10.23
Pretest 2	50	48.34	10.76
Posttest 1	50	66.63	9.01
Posttest 2	50	74.68	9.19

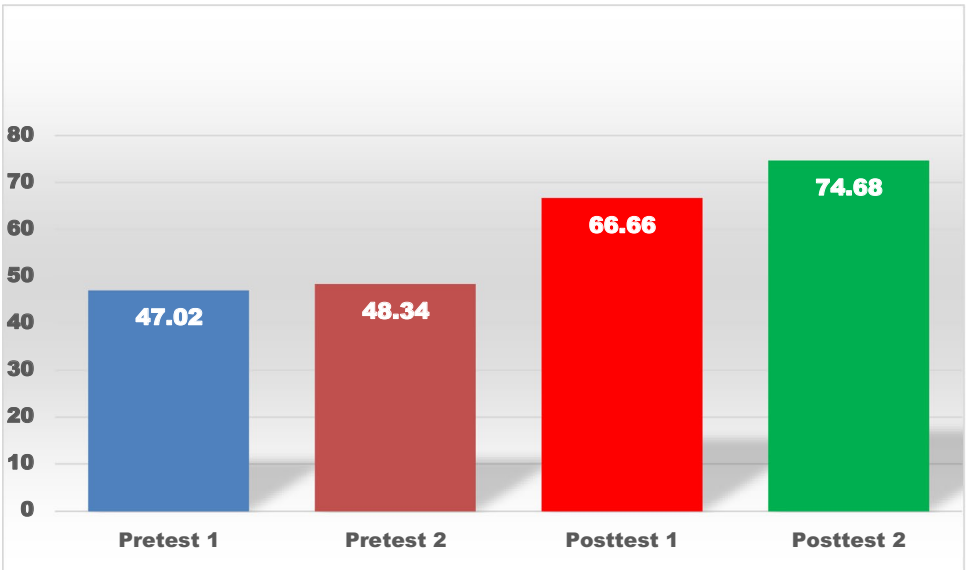

Fig. 2 Graphical illustration of the pretest and posttest scores of students' performance at different test occasions

Table 2 Kolmogorov–Smirnov test of normality

Time	Statistic	Df	P
Pretest 1	0.630	50	0.241*
Pretest 2	0.476	50	0.344*
Posttest 1	0.742	50	0.264*
Posttest 2	0.542	50	0.572*

*Not Significant, P > 0.05

respectively. It also revealed that M = 47.06, SD = 10.29 and M = 50.42 and SD = 11.45 at pre-test 2 for male and female respectively. Furthermore, the table also revealed that the students had M = 64.61, SD = 9.29 and M = 66.63, SD = 9.01 at posttest 1 for male and female respectively. It also revealed that M = 72.67, SD = 9.50 and M = 77.94 and SD = 7.22 at post-test 2 for male and female respectively. Moreover, the graphical illustration of the pretest and posttest scores of male and female students' performance at the different test occasions is presented in Fig. 3 below.

2.1 Testing of hypothesis

Ho_1: There is no significant difference in the mean achievement scores of pre-service teachers taught practical chemistry before and after exposure to the mobile learning application.

Table 4 reveals the RM-ANOVA of students' performance at different test occasions. The table revealed that $F_{(3,147)} = 109.475$, $P = 0.000$ and Partial Eta Squared effect size (ηp^2) = 0.916. This shows that the null hypothesis is hereby rejected, which indicates that there was a significant difference in the students' performance at different test occasions. Thus, the use of mobile applications has a significant effect on students' performance. Additionally, the effect size (ηp^2) of 0.916 means that 91.6% of the total variance in students' performance is linked to the use of mobile learning application. What this means is that the use of mobile learning application improved students' performance by 91.6% during the

Table 3 Mean and standard deviation of male and female students' achievement at different test occasions

Test	N	Gender	Mean	SD
Pretest 1	31	Male	48.32	10.47
	19	Female	44.89	9.71
	50	Total	47.02	10.23
Pretest 2	31	Male	47.06	10.29
	19	Female	50.42	11.45
	50	Total	48.34	10.76
Posttest 1	31	Male	64.61	9.29
	19	Female	66.73	8.79
	50	Total	66.63	9.01
Posttest 2	31	Male	72.67	9.50
	19	Female	77.94	7.22
	50	Total	74.68	9.19

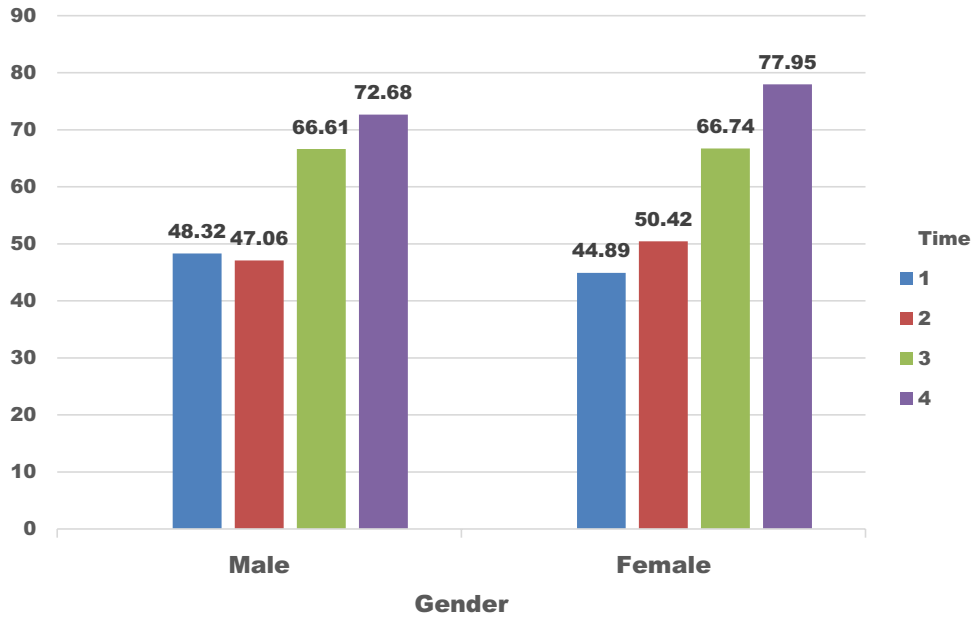

Fig. 3 Pretest and posttest scores of male and female students at different test occasions, Key: 1 = Pretest 1; 2 = Pretest 2; 3 = Posttest 1; 4 = Posttest 2

Table 4 RM-ANOVA of students' achievement in the various within subject test occasions

Source		Type III Sum of Squares	df	Mean Square	F	P	ηp^2
Time	Sphericity Assumed	28,078.575	3	9359.525	109.475	0.000*	0.916
	Greenhouse–Geisser	28,078.575	2.872	9775.148	109.475	0.000	0.916
	Huynh–Feldt	28,078.575	3.000	9359.525	109.475	0.000	0.916
	Lower-bound	28,078.575	1.000	28,078.575	109.475	0.000	0.916
Error(Time)	Sphericity Assumed	12,567.675	147	85.494			
	Greenhouse–Geisser	12,567.675	140.750	89.291			
	Huynh–Feldt	12,567.675	147.000	85.494			
	Lower-bound	12,567.675	49.000	256.483			

*Significant $P < 0.05$

treatment period. Furthermore, the table also revealed that Mauchly's test of sphericity for the within subject pairings was equally not significant (Mauchly (W) = 0.938; P = 0.691). This therefore means that the variance of all the within subject

Table 5 Sidak post-hoc pairwise comparisons of students' performance at four different test occasions

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	P	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Pretest 1	Pretest 2	− 1.320	2.020	0.987	− 6.858	4.218
	Posttest 1	− 19.640*	1.735	0.000	− 24.395	− 14.885
	Posttest 2	− 27.660*	1.770	0.000	− 32.512	− 22.808
Pretest 2	Pretest 1	1.320	2.020	0.987	− 4.218	6.858
	Posttest 1	− 18.320*	1.994	0.000	− 23.785	− 12.855
	Posttest 2	− 26.340*	1.894	0.000	− 31.533	− 21.147
Posttest 1	Pretest 1	19.640*	1.735	0.000	14.885	24.395
	Pretest 2	18.320*	1.994	0.000	12.855	23.785
	Posttest 2	− 8.020*	1.654	0.000	− 12.554	− 3.486
Posttest 2	Pretest 1	27.660*	1.770	0.000	22.808	32.512
	Pretest 2	26.340*	1.894	0.000	21.147	31.533
	Posttest 1	8.020*	1.654	0.000	3.486	12.554

*Significant $P < 0.05$

Table 6 RM-ANOVA of male and female students' performance at four different test occasions

Source		Type III Sum of Squares	Df	Mean Square	F	P	ηp^2
Treatment * Gender	Sphericity Assumed	515.042	3	171.681	2.051	0.109*	0.021
	Greenhouse–Geisser	515.042	2.852	180.579	2.051	0.113	0.021
	Huynh–Feldt	515.042	3.000	171.681	2.051	0.109	0.021
	Lower-bound	515.042	1.000	515.042	2.051	0.159	0.021
Error(Treatment)	Sphericity Assumed	12,052.633	144	83.699			
	Greenhouse–Geisser	12,052.633	136.904	88.037			
	Huynh–Feldt	12,052.633	144.000	83.699			
	Lower-bound	12,052.633	48.000	251.097			

*Not Significant $P > 0.05$

effect in all the different four test occasions is equal, thus satisfying the assumption of sphericity. In order to check the direction of the differences in significance, Sidak post-hoc pairwise comparison was conducted in Table 5.

Table 5 revealed the post-hoc pairwise comparison of students' performance in four different test occasions after exposure to mobile learning application. The table revealed that even though there was a significant difference between the pre-test and posttest scores of the students which indicates a periodic increase in performance as a result of the treatment, the significant difference between posttest 2 and pretest 1 was higher, followed by the significant difference between posttest 2 and pre-test 2.

Ho_2: There is no significant difference in the mean achievement scores of male and female pre-service teachers taught practical chemistry before and after exposure to the mobile learning application.

Table 6 shows the RM-ANOVA of male and female students' performance at different test occasions after exposure to mobile learning application. The table revealed that $F_{(3,144)} = 2.051$, $P = 0.109$, with an effect size of 0.21. This means that the hypothesis is hereby retained, thus signifying no significant difference in the mean achievement of male and female students after exposure to mobile learning. The partial eta squared effect size (ηp^2) of 0.21 means that 21.0% of the total variance in the performance of male and female students after the treatment is linked to the mobile learning treatment.

3 Discussion

The main aim of the study was to determine the effectiveness of a designed mobile application on pre-service teachers' performance in practical chemistry. After exposing the students to instruction using the mobile learning application, we discovered that the students' performance increased periodically in each of the test period as a result of the treatment. The null hypothesis was rejected which therefore means that there was indeed a significant difference in the performance of students exposed to mobile learning application. The finding of the study revealed that mobile learning application is directly linked to 91.6% of the total variance in students' performance after the treatment given the effect size of 0.916 that was recorded. This means that mobile learning application was responsible for improving students' performance by 91.6% which is categorized as a very high effect [11]. Our finding could be that with a mobile application, students have the liberty to learn at their own pace and construct meaning out of what they are being taught. This improvement in performance is very possible given the various features of mobile learning which makes it suitable for learning like portability [26], ubiquity [60], easing of learning process [54], fostering personalized learning [12], facilitating collaborative learning [37], ensuring autonomous learning [17, 51], and facilitating blended learning opportunities [6]. Additionally, mobile learning provides students with different learning resources to learn from like video lectures and interactive learning contents which could appeal to many learning preferences of students as noted in this finding. Additionally, mobile learning provides an avenue for learning to take place anywhere, anytime which could help to increase student' curiosity towards learning. The finding agrees with the several empirical studies [36, 42, 44, 14, 4, 27, 52, 30, 2, 63, 18, 22) that we reviewed in this study. Our finding, therefore, provides an insight into the effectiveness of enhancing pre-service teachers' performance in practical chemistry amongst pre-service teachers from the Nigerian perspectives.

Furthermore, the finding of this study revealed that there was no significant difference in the performance of male and female students after exposure to mobile learning. This means that both male and female students performed almost equally since the difference was not significant even though male students achieved a higher mean. The result also revealed that 21.0% of the total variance in male and female students' performance is linked to mobile learning given the effect size of 0.21 that was noticed which, according to Cohen [11], is categorized as small. This finding, however, could be due to individual differences which now form the basis for further studies to be conducted to further add to the frontiers of knowledge in the field of gender differences in mobile learning. This finding agrees with a number of studies [18, 29, 41] we reviewed in this study. However, on the contrary, it disagrees with some studies [13, 22] we reviewed which revealed a significant difference based on gender. These inconsistent findings, however, could be due to individual differences. This study thus now forms the basis for further studies to be conducted in order to further add to the frontiers of knowledge in the field of gender differences in mobile learning.

3.1 Implications of findings for practice and research

The finding of this study has a number of implications for chemistry teachers, policy makers and other science education researchers in Nigeria. It underscores the fact that if mobile learning could be incorporated in teaching chemistry practical in Nigeria, students' performance could be enhanced for it has what it takes to eliminate poor infrastructure and inadequate equipment. This finding revealed that the use of mobile learning has what it takes to encourage personalized learning thereby enabling students to construct meaning out of the learning process at their own pace thus leading to increase in performance. From the research perspectives, this finding has equally added to the scarce literature in the areas of research and development of mobile application for teaching chemistry practical in Nigeria.

4 Conclusion

This study revealed that the use of mobile learning for teaching practical chemistry amongst pre-service teachers is very effective and it equally enhances students' performance thereby leading to the tackling of poor performance and eliminating challenges during practical. Therefore, lecturers should be taught on how to implement mobile learning in their teaching and learning. Additionally, workshops should be organized in order to teach lecturers how to incorporate mobile learning.

4.1 Limitation and further research directions

This study has a number of limitations that should be addressed. First of all, the study was conducted on pre-service teachers of colleges of education in a Nigerian college of education; thus, similar study should be conducted on other pre-service teachers especially at the university levels to further test the effectiveness of the mobile learning application. The study was limited to a few practical chemistry aspects and as such, generalizations could not be drawn; therefore, similar studies should be conducted in other areas of chemistry. The study sample was small and therefore the generalizability of the study could not be established; as a result, similar studies should be conducted using a larger population in order to further establish the effectiveness of the mobile learning application.

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Author contributions FMS: Conceptualisation, writing draft, editing and approval. IAM: Conceptualisation, writing draft, editing, methodology, data collection, data analysis and approval. BMS: Conceptualisation, data collection, writing draft, development of mobile application and approval. FA: Project administration, supervision and approval AS: Technical support, software and approval.

Data availability Data is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate Informed consent was sought and the participants were assured of the privacy of their data in accordance with the best ethical research practices. The study was conducted in accordance with the standards of the Nigerian national code of research ethics (https://www.nhrec.net/nhrec/NCHRE_July%2007.pdf). Ethical approval was waived in this study by the Nigerian National Health Research Ethics Committee (NHREC) based on its guidelines providing exemption to studies in educational settings involving normal educational practices.

Competing interests The authors declare no competing interests.

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