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Design, development, and evaluation of a mobile learning application for computing education

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Abstract The study focused on the application of the design science research approach in the course of developing a mobile learning application, MobileEdu, for computing education in the Nigerian higher education context. MobileEdu facilitates the learning of computer science courses on mobile devices. The application supports ubiquitous, collaborative, and social aspects of learning among higher education students. Moreover, the application eases access to learning resources. The paper first describes analysis, design, and implementation activities related to the development of MobileEdu. Also, the paper deliberated on the characteristics and scope of the adherence of MobileEdu to the traits and ideas of design science research. To evaluate MobileEdu in a real-life learning setting, experiment was conducted with 142 third-year undergraduate students in a Nigerian university. Besides the learning achievement of the students using MobileEdu, the study examined the impact of MobileEdu on students' attitudes toward studying in a system analysis and design course. Experimental data were collected from pre- and post quizzes, interviews, and a questionnaire administered to students. The results of the evaluation are encouraging and showed that the MobileEdu application has a potential to improve students' learning achievements.

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In addition, the pedagogical experiences of students were mostly positive and students' attitudes toward the system analysis and design course through MobileEdu was better than those of students who studied the course via traditional methods. Finally, the study offered suggestions for how to implement effectively a mobile learning-supported course in computing curriculum.

Keywords MobileEdu · Mobile learning · Design science research · Blended learning · Computing education · Information and communication technology

1 Introduction

The proliferation of smartphones with advanced memory, processor, display, and battery capabilities has opened up wide opportunities for learners, instructors, and researchers. Learners are now able to receive and access instructions through several platforms, such as mobile apps, web-based, or combined mobile learning environments. Mobile devices and wireless technologies are continuously evolving with time. These technologies have taken a center stage in every aspect of our society, especially in education, health, the economy, and commerce. The use of mobile devices, such as smartphones, mobile phones, tablets, PDAs, MP3s, and pocket PCs, for computing education is constantly gaining interest among researchers and educators (Hürst et al. 2007; Ihantola et al. 2013; Jordine et al. 2015; Mahmoud and Dyer 2008; Mbogo et al. 2013; Moreira and Ferreira 2016; Prenner et al. 2014; Oyelere et al. 2016a; Tortorella and Graf 2017). These interests are boosted because of mobile devices' availability, low cost, technology infrastructure availability, and learners' interests (Oyelere et al. 2016a; Bidin and Ziden 2013; Oyelere et al. 2016b). Learners can now carry mobile devices anywhere, anytime to support their learning and personal activities. From our experiences, computing students are willing to learn through the support of mobile devices. Recent study (Osang et al. 2013) of mobile devices ownership among teachers and student is Nigerian university indicates that 97.5% of the teachers and 91.8% of the students uses mobile phones. The study shows that 66.3% of the teachers have smart phones such as blackberries and 24.1% of the students use such devices. Similarly, 90% of the teachers and 48.2% of the students already possess laptops. In addition, this new trend offers an exciting opportunity to indulge and attract students to the computing discipline. Although learning through mobile devices is envisaged as beneficial, especially in computing classrooms, learners' perception and experience will determine the success of this technological intervention.

In our work, we have applied the *design science research* (DSR) framework proposed by Johannesson and Perjons (2014) to develop a novel mobile learning solution, called MobileEdu, used in the Nigerian higher education context. DSR has been widely applied in information systems and educational technology research (van den Akker et al. 2007; Johannesson and Perjons 2014; Amiel and Reeves 2008; Anderson and Shattuck 2012), and the method is particularly suitable for mobile learning (de Villiers and Harpur 2013). DSR is a holistic research approach with dual aims. First, a concrete solution (artifact) is developed to solve a practical problem, fulfill a need, or requirement related to a real-life context. In our case, the real-life context is computing education in Nigerian higher education. The MobileEdu application was designed to support course instructors to handle a large populated undergraduate computing education course using a blended learning approach. The practical aim of our work is to leverage the affordance and ownership of mobile devices to facilitate the learning of computing courses via mobile learning. Second, DSR should expand the existing knowledge base related to the research area (Johannesson and Perjons 2014). In our case, the scientific inputs relate mainly to good practices and design principles that are crafted based on our experience of designing, developing, and evaluating the MobileEdu application. The objectives of this particular study are to describe the design and implementation activities of the MobileEdu mobile learning application, to reflect the development of MobileEdu based on the principles of DSR, and to analyze the experiences and attitudes of Nigerian higher education students who have been using MobileEdu in their studies. We also evaluated students' learning achievements and their perceptions toward MobileEdu. The study will answer the following research questions:

i. Is there an improvement in students' learning achievement after using MobileEdu for computing education in a Nigerian university?
ii. Does MobileEdu impact students' attitudes toward studying computing subjects, specifically system design and analysis topics?
iii. What are the pedagogical experiences of students using MobileEdu for computing education in a Nigerian university?

To answer the research questions, we conducted an experiment in a one-semester course. The participants of the experiment were a cohort of third-year computing students participating in the System Analysis and Design course at the Modibbo Adama University of Technology, Yola, Nigeria. MobileEdu was used as a technology intervention for administering the course, supporting students' learning experience and engagement.

There are several studies about mobile learning in Nigeria, but they are mainly theoretical and feasibility studies on mobile learning (Isiaka et al. 2011; Osang et al. 2013; Anohah et al. 2017; Oyelere et al. 2016b, c; Shonola and Joy 2015; Shonola et al. 2016). We are not aware of a similar study on the full implementation and evaluation of a mobile learning application for computing education in the Nigerian context. Thus, according to our knowledge, this is the first study in Nigeria examining experiences of undergraduate computer science students studying through a mobile learning application. Our results describe for the first time the learning achievement, pedagogical experiences, and perceptions of students using MobileEdu in a real learning setting.

2 Literature review

2.1 Relevance of mobile learning in an African context

Educational settings currently benefit from the opportunities created by networked mobile devices (Ozdamli and Uzunboylu 2015). Students and teachers carry their mobile devices that contain remarkable computing power, context awareness tools, wireless communication capability, and portability, making them reasonable tools for learning (Oyelere et al. 2016a; Sung et al. 2016). Since the inception of mobile learning, several researchers have tried to define the term. Early definitions considered mobile learning as simply the use of palm computational devices to support learning (Quinn 2000). Other definitions of mobile learning have been documented by prior researchers (Anohah et al. 2017; Sharples et al. 2005). We define *mobile learning* as the application of portable mobile computing devices, such as mobile phones, tablets, smartphones, and e-readers, to access learning resources, collaborate, communicate, and share learning experiences. However, mobile learning is not merely the use of mobile devices to support learning, but it also involves all the activities that occur between teachers, learners, learning environments, learning theories, and support for anywhere, anyone, anytime learning (Sharples et al. 2007). The core benefits of mobile devices, such as unlimited mobility, flexibility, and small size, are capable of introducing new opportunities for improving the learning environments in different forms, such as the engagement of users with mobile devices by assuming that students are constantly moving from one place to another, a dynamic process of developing skills and knowledge through training among peers, and learning taking place even in informal settings. Beside of supporting traditional face-face instruction, mobile learning solutions through the appropriate knowledge creation and distribution can also stimulate invention, as well teaching and learning approaches based on knowledge creation and distribution, such as social learning (Huang et al. 2010; Oyelere et al. 2016c), inquiry-based learning (Jones et al. 2013; Shih et al. 2010), blended learning (Minjuan et al. 2009), flipped learning (Hwang et al. 2015), online distance learning (Rekkedal and Dye 2007), game-based learning (Klopfer et al. 2012; Su and Cheng 2015), cooperative learning (Roschelle et al. 2010), collaborative learning (Kukulska-Hulme and Shield 2008), competition-based learning (Hwang and Chang 2015), active learning (Laurillard 2007), and exploratory learning (Liu et al. 2012). Consequently, mobile devices and wireless technology have the prospects of introducing cutting-edge innovations in education, especially the aspect of teaching methods. Such technology can also create a rippling effect on learners' performance, thereby not only helping to understand a particular subject, but also facilitating the development of skills such as problem-solving, teamwork, communication, creativity, innovation, and soft-skills. Leinonen et al. (2016) remarked that mobile apps designed for learning are in short supply. Due to the flexibility offered by mobile learning apps, academic institutions, universities, and colleges are designing and implementing various mobile learning apps to suit their particular curriculum and pedagogy needs (Alden 2013). Therefore, mobile learning encompasses broader activities of learners in any given setting, especially not limiting the learners to a fixed location or learning environment. It is relevant to researchers, practitioners, and other stakeholders to answer the following question in our literature review: Why is mobile learning relevant and important in the African context? The introduction of mobile devices to the African market has been particularly significant. People at the base of the income pyramid are now empowered through mobile technology to participate in society. Mobile devices' portability, flexibility, affordability, and simplicity make them important tools for educational purposes in settings where computers, the internet, and other basic infrastructure may be uncommon. Mobile learning can play a vital role in bridging the digital divide and reaching those who are outside formal educational settings. Mwangi et al. (2012)

recommended that mobile learning should be leveraged in both formal and informal settings to convey knowledge and skills. Velghe (2013) argued that the acceptance of the mobile phone in Africa has increased interest in literacy and introduced new opportunities to societies' deprived, marginalized, and less privileged. Technological innovations and contextualized learning opportunities offered by mobile learning are attractive and exciting to learners (Shonola et al. 2016). In the words of Kafyulilo (2014), "… mobile phones are considered as vital tools for both teaching and learning processes that can best serve as alternative device for overcoming the shortage of technological tools in schools in Tanzania and enhance students' learning from anywhere and at any time" (p. 2). However, to the authors´ best knowledge, very few studies are available in the literature that addresses the subject of developing a mobile learning system for computing education in an African context. One of such example is the mobile scaffolding application designed to facilitate learning of Java programming on mobile devices (Mbogo et al. 2013). The application was developed and evaluated in African university.

2.2 Mobile learning in computing education

Mobile learning in computing education is among the rapidly emerging technological interventions in the teaching of computer science subjects. A recent survey of mobile learning trends in computing education revealed that learners' affective traits are increased through mobile learning and the field has matured (Anohah et al. 2017). For example, the use of mobile learning in computing education is revealed to improve learners' hands-on experience and provide real-life examples of learning opportunities (Mahmoud and Dyer 2008; Mbogo et al. 2013). On the other hand, studies on the use of mobile learning in natural science courses have shown that it enhances learners' performance, pedagogical experience, and learning achievement (Chu et al. 2010; Liu et al. 2009). The positive influence of mobile learning recorded in Liu et al. (2009) was two-fold: (1) students' engage in mobile-technology supported *observation* during their scientific inquiry, and (2) students' engaging in mobile-technology supported *manipulation* during their scientific inquiry (p. 344). Translating these positive effects of observation and manipulation, especially mobile learning in computing education, would obviously amount to learning improvements, positive perceptions, and rewarding experiences. According to Mbogo et al. (2013), it is difficult for individuals to learn programming, especially novices, but mobile learning as a novel pedagogical method offers opportunities to minimize the difficulty. However, mobile learning solutions in computing education should be designed to support meaningful learning and provide motivation to students to adopt the solutions (Oyelere et al. 2016b). Table 1 presents several examples of mobile learning solutions in computing education from the literature that have also inspired our work with the MobileEdu application.

It is apparent from this table that several mobile learning solutions have been developed in computing education to support self-paced learning or to support the implementation of computing courses (Boyinbode et al. 2012; Bati et al. 2014; Hürst et al. 2007; Ivica et al. 2013; Karavirta et al. 2012; Pears and Rogalli 2011). However, the existing solutions have not been designed for an African higher education context. The mobile learning solution, MobileEdu, has been specifically designed to address the issues of poor engagement in teaching large students in undergraduate computing class

Table 1 Related mobile learning solutions in computing education

Solution	Short description	Results
Sortko (Ivica et al. 2013)	Development of an android-based Smartphone app to support the learning of sorting algorithms	The study discovered that students are motivated using technology for learning and the use of mobile devices prolonged learning
mJeliot application (Hürst et al. 2007)	In mJeliot, students can run and view visualizations of algorithm animations	The experiment conducted showed that mobile media players has prospects of improving learning of algorithms
Jeliot visualization (Pears and Rogalli 2011)	Integrated code execution features to Jeliot 3 and visualization tool displayed to students on their mobile devices	The study presented a mobile tool that facilitate active engagement of students with program codes through visualization. The application support individual feedback and collaboration among learners
RoboRun (Vinay et al. 2013)	In another example, mobile learning supports problem-based learning and games development to learn programming for school students	The game platform allows touch input devices for coding, learning conditional programming and algorithm sequence ordering
MobileParsons (Karavirta et al. 2012; Ihantola et al. 2013)	A Parsons problems-solving mobile learning application	The MobileParsosn solution extended the Parsons problems construction by minimizing the disadvantage of strict program scaffold through creative coding exercises
MMLS (Wen and Zhang 2015)	Micro-lecture mobile learning system which allowed learners to access videos and other micro lecture resources	MMLS connects microlecture and mobile learning to support ubiquitous learning. Students learning achievement was improved through the application
BML-CO (Moreira and Ferreira 2016)	The application that supports the teaching of requirement engineering through mobile devices	Application of mobile learning to requirements engineering course by adopting the Lucidchart application on mobile devices for systems modeling with UML
NetLuke (Prenner et al. 2014)	A mobile environment for the teaching of algorithms and data structure courses to undergraduate and graduate students	This work resulted in NetLuke, interactive algorithms, and a data structures visualization tool. The NetLuke tool supports direct data input by the user, the loading of existing visualization samples, and dynamic animations
Program scaffolding mobile application (Mbogo et al. 2013)	An Android-based mobile application that supports program scaffolding	The result of the study was a mobile learning application developed according to five-level scaffolding framework to support learning of programming. This work was developed in African context
MobileEdu (Oyelere and Suhonen 2016)	A mobile application to facilitate the learning of computing science courses on mobile devices	The study resulted in a mobile learning application for computing education. The application supports engagement and interaction among learners in Nigerian higher education context

in a Nigerian university context (Oyelere and Suhonen 2016). Moreover, there is need to continuously design new and all-inclusive mobile learning platforms based on scientifically proven theories and emerging frameworks such as DSR.

3 Design science research framework

Design Science Research (DSR) is a systematic study of developing solutions to practical problems emerging from real-life situations and settings (Johannesson and Perjons 2014). According to Hevner et al. (2004), DSR is about "*using a rigorous process for the purpose of designing artifacts in order to solve some observed problems, evaluating designs, making research contributions and then communicating these results to the scientific community.*" DSR does not start from a certain theoretical or methodological problem, but the recognition that something needs to be changed or improved (Dishman 2003; Eagleton 1983). According to Johannesson and Perjons (2014), the starting point (i.e. practical problem) of DSR can be an undesirable state of affairs, or a gap between the current state and a desirable state. The practical problem can also be a puzzling question, or an unexpected circumstance, or a clear identified need for a change or improvement. In some cases, relevant practical problems are not perceived until new innovative solution is introduced, which shows that the current practice can be improved. For example, our aim is to design a mobile learning solution to meet the needs and requirements of computing educators in a Nigerian higher education context.

During a DSR process, several concrete outputs are possible, including methods, constructs, designed objects, instantiations, social innovations, models, recommendation and good practices, software applications, and even new theories (Hevner et al. 2004). For example, design principles discovered during the DSR process can be used to guide and assist the future design efforts (Järvinen 2007). In DSR, there is a continuous interaction between the designed solution and the design process, since increased understanding of the problem and the solution to solve the problem should improve both the quality of the solution and increase the existing understanding about the design process (Simon 1969). Educational design science has been defined by van den Akker et al. (2007) as the study of designing, developing and evaluating educational programs, processes and products to problems emerging from real-life settings. According to Winter (2008) and Reeves (2006), the crucial characteristics of educational oriented design research are: (1) gain holistic understanding of the addressed complex educational problems in collaboration with practitioners; (2) identify the most promising features for the plausible solution, (3) build prototypes including the promising features, (4) test and evaluate the implemented solutions out in real-life settings, (5) conduct rigorous and reflective inquire to refine innovative solutions as well as to define new design principles. Thus, DSR has potential to promote the practical relevance of educational technology research (van den Akker et al. 2007).

The DSR framework presented by Johannesson and Perjons (2014) was employed in the development of MobileEdu. Hereafter, we use the acronym *JPDSR* to refer to their framework. The JPDSR framework consists of the following activities: explicate the problem, outline the artifact and define requirements, design and develop the artifact, demonstrate the artifact, and finally, evaluate the artifact (see Fig. 1). Several

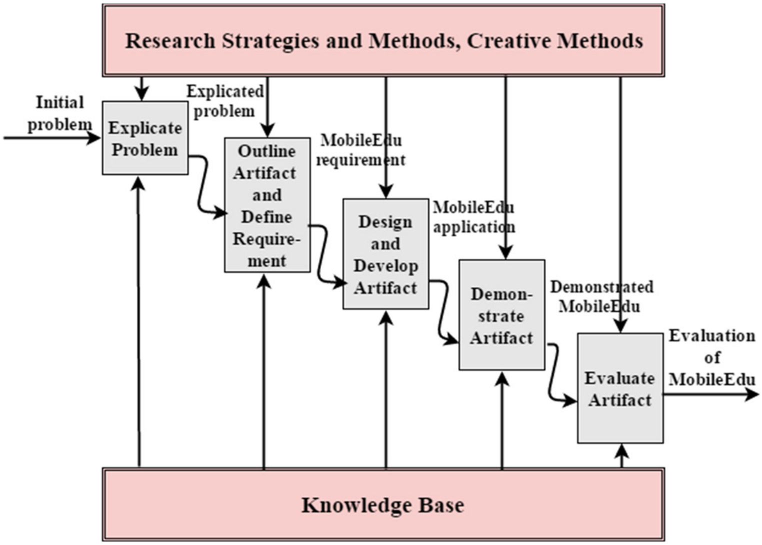

Fig. 1 Design science research framework adapted from Johannesson and Perjons (2014)

research approaches could apply in different activities, and all activities of the DSR process can contribute to the body of knowledge related to the field of study or studies connected to the research work.

The first activity in the JPDSR framework is *explicating the problem*, which means the practical problem behind the DSR process should be clearly formulated and motivated by showing that it is significant to solve (Johannesson and Perjons 2014). The problem should be also of general interest, e.g., significant not only for one local practice. Finally, the underlying causes of the problem should be identified and analyzed. The main goals of the first phase are to clarify the initial problem, position the problem in the practice where it appears, formulate the problem precisely, and motivate the importance of the problem. The second activity in the JPDSR framework is *outlining the artifact and defining the requirements*. The purpose of the activity is to define requirements and expectations based on the identified practical problem. The second activity also contributes to the creation of preliminary draft solutions(s) to the explicated problem by transforming the requirements and expectations into functional demands of the proposed solution (de Villiers and Harpur 2013).

In the third activity, *design and develop the artifact*, the aim is to develop a concrete solution that addresses the explicated problem and fulfills the defined requirements (Johannesson and Perjons 2014). The design of an artifact includes determining the functionality of the solution as well as its construction. For example, participatory design principles, agile design approaches and quick development principles are relevant when the identified requirements are transformed into specifications, prototype solutions and finally fully functional products. In the *demonstrate activity*, an early version of the implemented solution is used either as an illustrative case or a real-life case with the aim of analyzing the feasibility of the solution. The aim of the proof-of-concept type of evaluation is to show that the solution can solve the identified practical problem (Johannesson and Perjons 2014). In the *evaluation* activity, various testing, evaluation and experimentation approached can be used to investigate and evaluate how well the solution fulfils the identified requirements and to what extent the implemented solution can solve, or alleviate, the practical problem that motivated the research, i.e. what is the impact of the solution (Johannesson and Perjons 2014). Formative evaluation methods can be used to collect feedback and improve the solution, while summative evaluation is used to measure the impact of the solution. According to Tsai et al. (2013), mixed methods approaches are especially relevant to DSR to integrate empirical principles of knowledge creation (controlled experiments and quantitative analysis) with approaches to understand and analyse human experience (qualitative methods). One important aspects of JPDSR framework is that a DSR project is executed in an iterative and progressive way, moving back and forth between all the activities of problem explication, requirement definition, development, and evaluation. The analysis-build-evaluate loop is typically iterated several times to see how the solution work, and then constantly revise the solution based on evaluations in real-life settings (Collins et al. 2004; Simon 1969).

4 Design and development of MobileEdu

4.1 Explication of the problem behind MobileEdu

The practical challenge that motivated the development of MobileEdu is a lack of direct engagement and interaction between teachers and learners due to a large number of students in undergraduate computer science classes in the Nigerian higher education context. Practically speaking, in developing countries such as Nigeria, there are massive numbers of students enrolled in public universities. Often, teachers are faced with the challenge of giving attention to hundreds of students in an undergraduate program. The large number of students has created, for example, problems such as fewer contacts between students and teachers; poor management of learning activities; ineffective achievement of instructional goals involving higher-level cognitive skills, such as analysis, synthesis, and application; poor morale, motivation, and self-esteem among learners and teachers; and limited opportunities for individual feedback and student assessment (Kerr 2011). Although these problems are typical in developing countries, they could be of general interest.

Our earlier studies contributed to the explication of the problem in the following ways. First, to define the problem, consultation was initiated with stakeholders, through face-face discussions, questionnaires, and interviews (Oyelere et al. 2016b). We also investigated Nigerian higher education students' readiness to adopt mobile learning, their preferences to use specific mobile learning devices and mobile learning solutions for computing courses, and their opinions regarding the suitability of mobile learning for learning ICT-related subjects. Subsequently, we conducted a systematic literature review to identify existing solutions and research results regarding mobile learning in computing education (Anohah et al. 2017). The systematic review explored perspectives on mobile learning integration into computing education, such as applications, developments, and the design of mobile learning solutions, which then also inspired the refinement of the requirements, and eventually the design and development of the MobileEdu system.

The opportunity in the affordance of mobile devices in Nigeria compared to other ICT tools, such as laptops, is an important consideration when developing mobile learning platforms. There is a rapid increase in mobile device ownership due to affordability (Oyelere et al. 2016a). Therefore, it is important to leverage this affordability for learning. We also wanted to design and develop the MobileEdu system to support the learning of computing subjects on mobile devices through blended learning instead of traditional face-face classroom learning. In blended learning, learners could learn through online media and face to face, which could allow instructors to reach more students. Currently, the learning environment in Nigerian higher education is predominantly traditional face-to-face instruction, where instructors and learners are situated in a particular confined location. While this learning situation has been successful for decades, it is quite demanding for instructors to reach every individual learner without ICT interventions, such as mobile learning. The re-conceptualization of learning to identify the crucial role of mobility, collaboration, and communication, especially for the mobile age, has been emphasized (Sharples et al. 2005). Therefore, it is relevant and novel to identify pertinent technologies and incorporate them to ameliorate learning issues.

4.2 Outline the solution and define the requirements

The main functional requirement for MobileEdu is the capability to support the learning engagement of numerous students at any point in time. As argued in Laurillard (2007), learning in large classrooms is one source of decline in students' active engagement and teachers' interaction with their students. A blended learning approach is considered one option to minimize the impact of large classrooms and improve learners' performance (Mwangi et al. 2012). One way to support learners' engagement in mobile learning is to employ mobile communication functions, such as chat, email, push notifications, discussion forums, and interactive self-practice materials (Liu et al. 2012). All these functions are available on MobileEdu, creating on-demand access to information. Another requirement satisfied by MobileEdu is leveraging the affordance of mobile devices, evolving technologies, user acceptance of mobile devices, and support for learning anywhere, anytime. For example, MobileEdu supports the uploading of micro lecture materials and the use of devices' features, such as mobile data, Bluetooth, Wi-Fi, and GPS. Mobility, social network, and context awareness are important functions to twenty-first-century learners, as opined in (Oyelere et al. 2016a). Other requirements satisfied by MobileEdu are the opportunity for blended learning consisting of mobile learning-based activities, large classroom teaching and small-group lab, and assessments (Jordine et al. 2015). Thus, MobileEdu supports students to access learning notes in various formats—such as .doc, .pdf, and .ppt—view announcements, post discussions, create learning contents, attempt quizzes, and receive notifications.

4.3 MobileEdu application design and development

MobileEdu consists of a mobile server broadcasting sub-system to share data and resources among all mobile devices connected to the server as well as a classroom management and administration sub-system where all activities for blended learning, collaboration, social networking, and learning assessment are carried out. The physical structure of MobileEdu consists of the learning center, the clients (users), system administration panel, and the server. MobileEdu learning center is the heart of the entire system. It is comprised of seven tabs to achieve the requirements outlined for MobileEdu. *My Class* supports various courses, activities of users, such as selecting courses and identifying classmates for discussion, and a quiz system for assessment. *Library* gives access to open-source electronic learning materials, notes, slides, and an option for learners to turn in tasks, such as assignments and homework. *Messages* supports collaboration activities and private messages among learners and instructors. *Friends* is responsible for enabling social networking and the choice of friends for communication purposes. *Groups* is another social networking and collaboration function; students are grouped to complete learning activities. *Blogs* supports information and the sharing of ideas among learners; *Announcements* provide updates on upcoming activities.

4.4 MobileEdu system implementation

The first working version of MobileEdu is an Android-based mobile application. As described in the design phase, the entire system consists of the clients (Android-supported mobile device), system administrator, database, and the server. To ensure the system's portability, efficiency, and maintainability, we built each subsystem using different software technology. The subsystems are connected using a dynamic link library. After developing the application, we ran it severally on the emulator and actual device to confirm the functionality of the different units. Then, we installed the application on real mobile devices for debugging. The testing was done on a 7.1-in. Samsung Galaxy S3 mini and 10.1-in. Samsung Galaxy Tablet. The implemented artifact went through rigorous fine-tuning and iteration, as prescribed by DSR. The DSR framework for MobileEdu is illustrated in Fig. 2. The MobileEdu app is available on the Google Play Store. The app can be downloaded free of charge, but requires registration by users.

The MobileEdu home screen contains seven tabs for carrying out learning activities. Both instructors and learners are welcomed with the *My Class*, *Library*, *Messages*, *Friends*, *Groups*, *Blog*, and *Announcement* tabs. Figure 3 depicts a screenshot of the

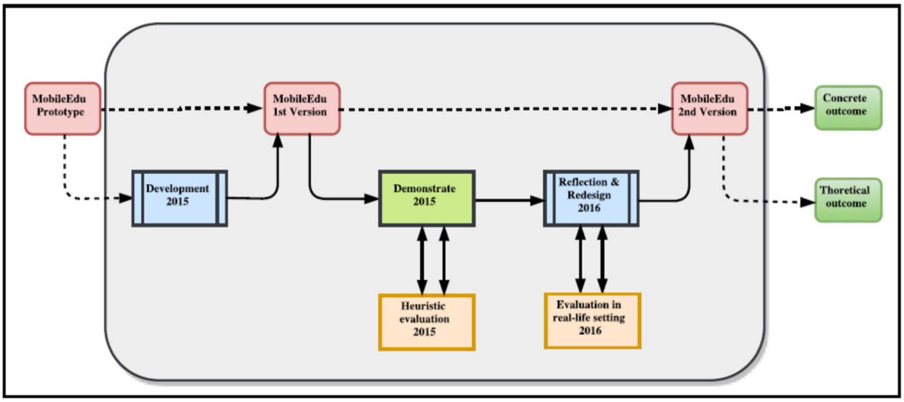

Fig. 2 Summary of the MobileEdu DSR process

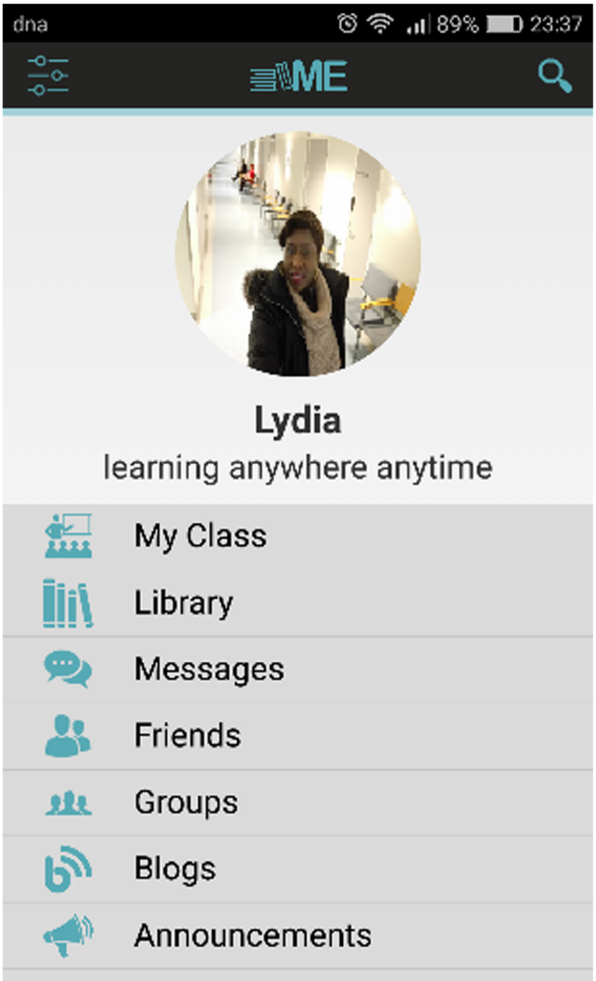

Fig. 3 Home screen

home screen. The MobileEdu system administrator is responsible for setting up the course and managing users. The teacher, after securing authentication, can set his profile, select his course from *My Class* tab, and connect with the students who have selected the course. Afterward, the teacher is able to give learning resources, links, and quizzes, create groups, create blogs, upload announcements, send/receive messages, and receive students' assignments. The students similarly would need to obtain authentication and then access the mobile learning platform. Authentication is mandatory to protect the teacher and learner works, copyrights, privacy, and the identification of learners (Shonola and Joy 2015; Oyelere et al. 2016a). Subsequent to authentication is profile personalization to support teachers' and students' context awareness and learning. Users have the opportunity to personalize their profile by updating profile picture (an image or photo that depicts users), display name (users' identification name), tagline (texts related to users), password (secret key to access the platform), and location (users' current position on the GPS).

The profile information will uniquely identify users and create learning contextualization. *My Class* tab supports users with functions such as *Activities* (offering a view of their activity timeline), *Courses* (lists users' subscribed courses), *Mates* (lists course mates), *Discussion* (course chat among learners and teachers), and *Quiz* (tests to evaluate learners' course performance). Figure 4 shows students' quiz interface. The quiz interface supports multiple-choice and true/false question types. Three functions are represented in the *Library* tab: the *e-library* provides a link to open-access electronic resources and course-related materials, the *Library*-tab supports learners with instructors' teaching materials, such as slides, videos, audios, animations, and notes, and the *assignment*-tab supports learners to upload completed tasks. Learners can access these materials on the go and store the resources on the mobile devices' memory for continuous studies. Figure 5 depicts a screenshot of the *Library* tab. Learners and instructors can send and receive private emails

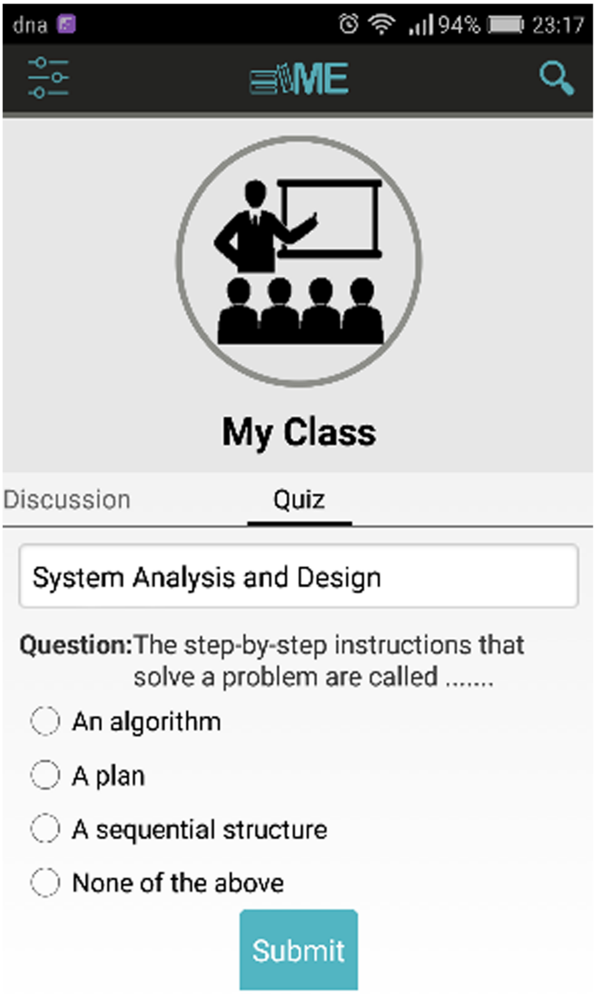

Fig. 4 Student's quiz screen

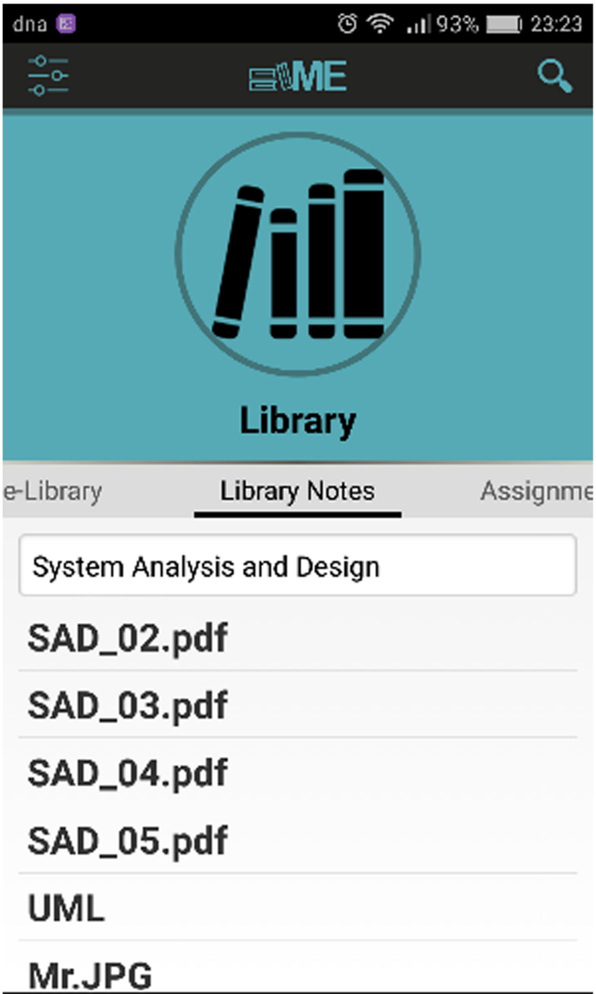

Fig. 5 Library tab

through the *Messages* tab. This aspect is essential, especially for instructors to discuss important concepts directly with a learner and support peer-to-peer messaging. Before sending a message to users, individuals must be friends on the platform. The *Friends* tab (see Fig. 6) offers a view of users' current friends and friend invites. The *Group* tab supports learners' teamwork and collaborative activities. Teachers can place learners into groups to perform learning activities together. The *Announcement* tab contains a function for passing information about course activities and other relevant news. The originality of our solution lies in the fact that the MobileEdu system is all-inclusive to support blended learning for numerous students, while providing an opportunity for assessment, collaboration, and social networking. Figure 7 represents an abstract model of the entire MobileEdu system using a UML use case diagram. The actors (lecturer, student, and administrator) are shown interacting with the system functions.

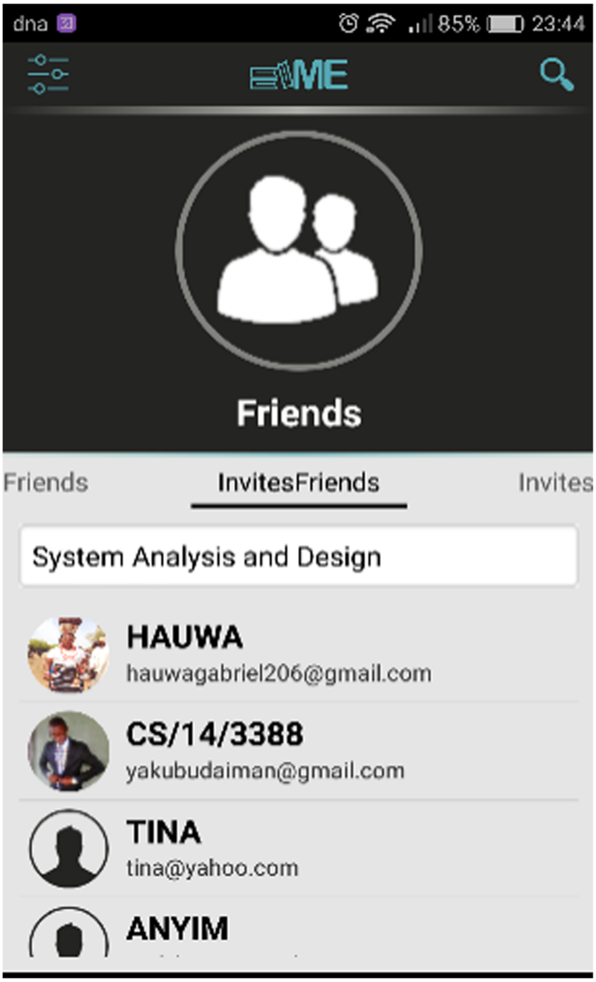

Fig. 6 Friends tab

5 Experiment design – the first evaluation of MobileEdu

To evaluate the feasibility, effectiveness, and suitability of MobileEdu in computing education, we conducted an experiment in the Nigerian higher education context. The aim of this experiment was to assess the viability of the artifact-MobileEdu, by validating if students who learned through MobileEdu attained improved learning engagement, results, and had better pedagogical experiences than those who learned by following the traditional face-to-face method. We also evaluated the attitudes and perceptions of students in the experiment. During the experiment, MobileEdu was used in a Nigerian university computer science course to support messaging, quizzes, discussions, and group work activities. Course materials and self-practice micro lecture learning objects were uploaded into the application in different file formats, such as document and text file formats (e.g., doc, txt), e-book file formats (e.g., pdf, htmlz), graphic and image processing formats (e.g., jpg, png), audio and sound file formats

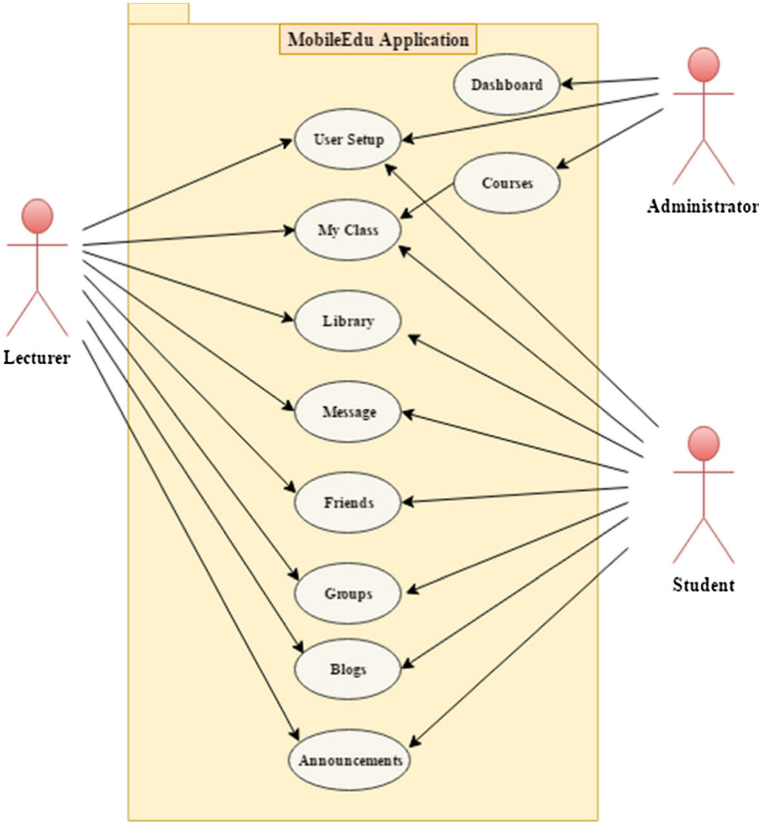

Fig. 7 UML use case diagram of MobileEdu system

(e.g., mp3, wav), video file formats (e.g., mpeg-4, 3gp), source code and script files (e.g., src, html), and spreadsheet and workbook files (e.g., xls, ods). These learning objects support digital learners' needs, such as mobility, contextualization, and social networking (Oyelere et al. 2016a). The course slides, notes, short videos, and homework were shared via MobileEdu. Learners were assigned to teams to complete group tasks and were encouraged to work together during the learning process on MobileEdu. Furthermore, the learners used the social networking features on MobileEdu to collaborate, engage, and actively socialize while learning.

5.1 Research context and participants

The study was conducted in the Department of Computer Science at the Modibbo Adama University of Technology Yola, Nigeria. Participants in the experiment were third-year computer science program students participating in the System Analysis and Design course. The demographic results indicate that 37% of the sampled respondents were female and 63% were male. The largest age group that responded was 21–25 years (72%), followed by 26–30 years (22%), 31–35 years (3%), and 16–20 years (only 2%). There were 142 participants divided into two groups for the purpose of the experiment. One group was designate as the control group having 71 students, and the other was the experimental group having 71 students as well. Students in control group learned through face-to-face traditional method only. The students in experimental group learned entirely through MobileEdu application.

5.2 Learning activity and experiment design

The System Analysis and Design course is a mandatory course taught in all computer science curricula of Bachelor of Technology degrees in Nigerian universities. The course is taught for one semester and is broadly intended to present state-of-the-art systems development strategies, tools, methods, and practices (see Table 2 for the course content and schedule). In the first phase of the course activities, the instructor used two weeks to guide students on the basics of systems analysis and the definition of course terms. In addition, all participants were introduced to the concept of mobile learning and guidelines on the usage of MobileEdu. The idea was to place the learners on the same level before the experiment. Figure 8 depicts the entire investigation procedure.

Table 2 Course content and schedule

1st week:	Introduction to MobileEdu, user guides tutorial & introduction to system analysis course
2nd week:	Systems development methodologies
3rd week:	Understanding of organizational systems for modeling
4th week:	Fundamentals of IT project management
5th week:	Information gathering & methods
6th week:	Application of data flows diagrams
7th week:	Designing inputs & outputs
8th week:	Designing systems databases
9th week:	Object-oriented systems analysis & design using UML
10th week:	Human-computer interaction
11th week:	Agile modeling & prototyping
12th week:	Design & implementation of quality assured systems
13th week:	Course summary & revision

In the second phase, after receiving basic knowledge on the course and assuming that all students are on the same learning scale, a 30-min pre-quiz was administered to all students. The aim of the quiz was to evaluate students' fundamental knowledge of the course. During the third phase, the remaining lessons were taught over a period of eleven weeks. Students in the experimental group used the MobileEdu application to learn and connect with their colleagues online, anytime, and anywhere. Experimental group students had the opportunity to share ideas, knowledge, and materials outside the classroom hours. They posted questions to the teacher anytime and requested help about unclear topics. Besides, students in the control group depended only on the face-to-face instruction and in-class interaction with their colleagues. After the thirteen weeks of instructions and completing all course activities (two weeks for introduction and eleven weeks for lessons), the students undertook a 90-min post-quiz and responded to the 30-min questionnaire.

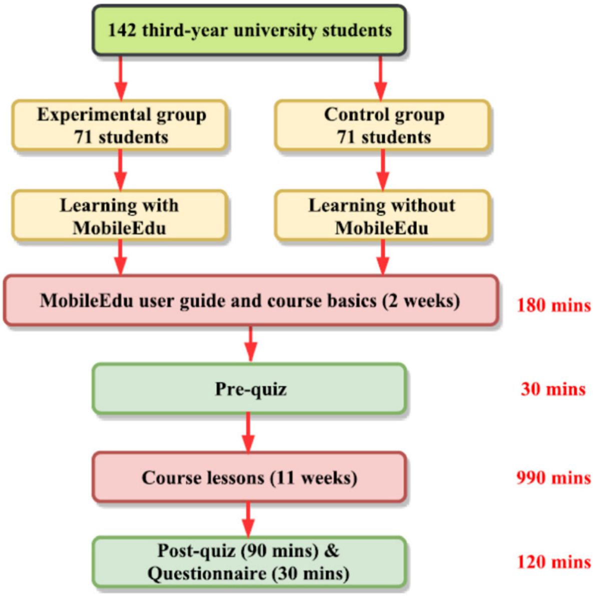

Fig. 8 Investigation procedure

5.3 Research instruments

The research data in this study is drawn from four main sources: pre-quiz, post-quiz, interviews, and questionnaire. The pre-quiz and post-quiz were developed to evaluate students' learning achievement. The intention of the pre-quiz was to confirm that both experimental and control group students had equal fundamental knowledge of the system analysis course. The pre-quiz contained 30 multiple-choice items. The post-quiz contained 25 fill-in-the-blank items, 20 multiple-choice items, and 25 true-or-false items. The post-quiz covered all topics of the course and focused on assessing students' knowledge of the system analysis and design course. Although quiz questions were sourced from publishers of course materials, three expert instructors evaluated the questions to ascertain their validity. In-depth one-on-one interviews were conducted with 10 students who participated in the course. The purpose of the interview is to assess students' pedagogical experiences, perceptions, and attitudes on the use of MobileEdu for computing education. Furthermore, a questionnaire was administered to all students to gather their perceptions, attitudes, and pedagogical experiences about the System Analysis and Design course. The questionnaire contained 10 six-point Likert-scale items, where 1 represented *strongly disagree* and 6 represented *strongly agree*. Respondents completed the questionnaire within 30 min. To ensure the validity of the questionnaire, two experts were engaged to review its contents. Thus, the quiz and questionnaire was finalized based on experts' opinion.

5.4 Data analysis

A combination of quantitative and qualitative approaches was used in the data analysis. Data collected were analyzed through the SPSS 21 software (IBM Corp. 2012). During

Table 3 Descriptive statistics results of pre-quiz learning achievement

	Group of students	N	Mean	SD
Pre-quiz	Control	71	13.83	4.31
	Experimental	71	13.80	4.79

the data analysis, the means, standard deviations, and percentages were determined, and t-tests and analysis of covariance (ANCOVA) were performed. A confidence interval of 95% (0.05 significance level) was used for the interpretation of data.

6 Results

6.1 Research question 1: Students' learning achievement

To answer the research question—Is their improvement in students' learning achievement after using MobileEdu in computing education in a Nigerian university?—we first analyzed the data obtained from pre- and post-quizzes. An independent t-test was used to analyze the pre-quiz data, confirming that students in the two groups had equal learning abilities after obtaining basic knowledge of the course; the descriptive statistics results are presented in Table 3.

From Table 3, t-test results showed that there was no significant difference ($t = 0.037$, two-tailed $p = 0.97$) between the control and experimental groups. That is, the two groups of students considered in the experiment had statistically equivalent abilities at the beginning of the course. An analysis of covariance (ANCOVA) was performed on post-quiz, and results are presented in Table 4. During the ANCOVA, pre-quiz scores were used as a covariate. From the post-quiz learning performance scores, we deduced that the experimental group's average learning performance and achievement are significantly better than students in the control group, ($F = 7.14$, $p < 0.001$). Furthermore, we computed the effect size, d, which is a measure of the magnitude of a treatment effect between the two groups (Cohen 1988). According to Cohen's benchmark, the effect size is defined as *small*, $d = 0.2$, *medium*, $d = 0.5$, and *large*, $d = 0.8$. In our study, the Cohen's d value of 0.59 indicates a *medium* effect size. This shows that the use of MobileEdu has helped to improve students' learning achievement.

Table 4 Descriptive statistics and ANCOVA results for the post-quiz learning achievement

	Group of students	N	Mean	SD	Adjusted mean	Std. error	F value	d
Post-quiz	Control	71	44.76	9.86	44.75	1.17	7.14*	0.59
	Experimental	71	50.65	9.93	50.65	1.17		

*$p < 0.001$

Table 5 Descriptive statistics results of questionnaire

	Group of students	N	Mean	SD	t
Perception and attitude (items 1–7)	Control	71	3.01	0.76	−15.45
	Experimental	71	5.12	0.85	

6.2 Research question 2: Pedagogical experiences, perceptions, and attitudes

To answer the research question concerning the pedagogical experiences and attitudes of students using MobileEdu in computing education in a Nigerian university, we analyzed data using both quantitative and qualitative methods. In the case of quantitative approach, a questionnaire was administered to obtain students' experiences, perceptions, and attitudes on the course. Descriptive statistics results obtained from the t-test analysis of the questionnaire are presented in Table 5. The perceptions and attitudes of experimental group students were significantly better ($t = -15.45$, $p < 0.0001$) than the students in the control group.

Furthermore, we conducted an item-by-item analysis of students' perceptions and attitudes toward the System Analysis and Design course. The results are presented in Table 6. The descriptive statistics results indicated the differences between the two groups on each perception and attitude item in the questionnaire. Table 7 shows the t-test results for the students' pedagogical experience items. The pedagogical experience of experimental group students was significantly better ($t = -4.53$, $p < 0.0001$), than students in the control group. The use of the MobileEdu application for learning is an effective way to improve the pedagogical experience of students. Additionally, we conducted an item-by-item analysis of

Table 6 Descriptive statistics results of questionnaire about students' perception and attitude

Students' perception and attitude	Control group (Mean/SD)	Experimental group (Mean/SD)	t
Q1. After participating in the course, I am more interested in observing and exploring the features of system analysis and design	2.59/1.44	4.57/1.56	−7.87
Q2. After participating in the learning activity, I am more confident in applying concepts of system analysis and design	2.87/1.34	5.14/0.86	−11.96
Q3. I am more interested in taking programming course after participating in this learning activity	2.81/1.33	5.25/0.87	−12.87
Q4. I care more about collaborating with peers when learning computer science concepts after participating in this learning activity	2.43/1.13	5.08/1.21	−13.43
Q5. I prefer to take the system analysis and design course via project activities in group	3.05/1.41	5.18/1.04	−10.19
Q6. I will actively try to observe the features of other system design tools	2.77/1.39	5.16/0.81	−12.50
Q7. The teaching approach of the course is motivating for me	4.54/1.30	5.43/0.52	−5.30

Table 7 Descriptive statistics results of questionnaire about students' experience

	Group of students	N	Mean	SD	t
Experience (items 8–10)	Control	71	4.51	1.40	−4.53
	Experimental	71	5.34	0.65	

students' pedagogical experience in the course. The results are presented in Table 8. The descriptive statistics results indicated the differences between the two groups on each pedagogical experience item in the questionnaire. The experimental group students indicated that they had a better learning experience in the course.

6.3 Interviews

In the case of qualitative analysis, we conducted in-depth one-on-one interviews to determine participants' pedagogical experiences, perceptions, and attitudes about MobileEdu. The first stage of the interview data analysis was reading the transcripts, labeling relevant pieces, deciding which codes are the most important, and creating categories by bringing several codes together. Vital information about students' experiences, perceptions, and attitudes toward MobileEdu were retrieved through coding. During the second stage, data obtained were formulated for the experimental settings' description and interpretation. According to Rubin and Rubin (2011), the worth of a study is established through identified themes and their correlation with the research questions. The identified themes are summarized in Table 9.

7 Discussion

The purpose of the study was to evaluate MobileEdu, a mobile learning application developed especially for the context of developing countries, such as Nigeria. Our attention was focused not only on MobileEdu's potential to improve students' learning achievement, but also on the pedagogical experiences and attitudes of learners. It is anticipated that learners' familiarity and experience with the MobileEdu tool is

Table 8 Independent t-values on items for students' experience

Students' pedagogical experience	Control group (Mean/SD)	Experimental group (Mean/SD)	t
Q8. System analysis and design process have become clearer after participating in this course	4.42/1.32	5.32/0.73	−5.01
Q9. The topics covered in the learning activities are relevant to the system analysis and design course	4.50/1.47	5.33/0.79	−4.18
Q10. I will recommend technology-based teaching and learning of computer science courses	4.61/1.60	5.38/0.70	−3.65

Table 9 Analysis of students' opinions regarding MobileEdu

Theme	Aspects	Example quotations
Improved learning achievements	Quick and easy information access	"Overall, I felt using MobileEdu helped me to access learning materials anywhere anytime to study, thereby improving my test score"
	Ubiquitous learning	"It was entirely a new experience to engage with course notes. I could ask for support from peers about the course"
	Communication with peers	"My learning output has increased by the mobile learning application"
	Increased engagement with learning materials and content sharing	
	Use of application is convenient and allow flexibility	
Personalized learning experience	Appreciation towards personal learning opportunity	"I now learn at my pace thus focusing on facts"
	The application offered a change from the traditional face-face teaching to new digital, blended learning	"I perform better when I set my own goals and get feedback from the teacher"
	MobileEdu matched students learning preferences, timing and style	"As a substitute for sitting and listening to lecturer, I was really involved and receiving direct experience"
Technical and usability issues	Problems with internet connectivity issues, poor network reception to download and upload files	"I find it difficult to download the application from google play store"
	Cost of using the application	"I had to uninstall and reinstall severally"
	Incompatibility of MobileEdu to operating systems other than Android	"It is expensive to buy data for internet access"
		"Slow internet connectivity makes it hard to access MobileEdu
Features of the application	Class, Library, Announcement, Blog, and Groups features received positive feedback	"Groups tab is working well because when we are assigned into groups, we work together with peers successfully"
	Student reported problems with Library tab	"I can see my course mate and interact with them, and message a friend on MobileEdu"
	Suggested features to the application: examination grading, educational games, and local educational contents	"I like the announcement feature because I can see the teacher's notices about class activities, assignment, venues, and timelines"
		"Library tab is not working well because I cannot see the status of my upload, and also login/logout feature is not working fine, it should retain login credentials since it is my personal mobile devices."
Perception and attitude towards mobile learning application	Learning materials and course contents were effectively organized to support learning	"The Class tab helps to identify my courses easily and the Library tab aided us to access learning materials."

Table 9 (continued)

Theme	Aspects	Example quotations
	Using mobile learning application engaged student in pleasant experiences and enhanced their attitude and perception towards learning	"MobileEdu meet my expectation as a learning tool because I have it handy"
	Enhancement of teamwork and collaboration experience	"I enjoyed group chat with classmates"
		"Good for the teachers because it the fastest means of getting in touch with students"
		"I can see my colleagues' discussions and chats on the platform."

indispensable to ensure positive usage in computing education. Therefore, our study investigated the potentials offered by mobile learning solutions and ascertained users' perceptions.

We discovered that there was a significant improvement in students' learning achievement after using MobileEdu in computing education in a Nigerian university. At the commencement of the study, learners had identical levels of the basic knowledge necessary for participating in the course. We compared the performance of two groups of learners (those using MobileEdu and those not using MobileEdu) using an independent t-test by examining their pre-quiz performance. The two groups did not statistically differ before the experiment. We then administered treatment over 11 weeks of lessons and conducted a post-treatment test. The ANCOVA analysis performed on learning performance scores indicated that the experimental group, which used MobileEdu to support their learning, outperformed the control group, which did not use MobileEdu. These results were consistent with other studies that have shown that the application of mobile learning interventions could improve students' learning performance (Chu et al. 2010; Liu et al. 2009). Our study is slightly different in focus from previous work, for example in Bidin and Ziden (2013), Isiaka et al. (2011), Liu et al. (2012), Ozdamli and Uzunboylu (2015), Shonola et al. (2016), and Sung et al. (2016), which predominantly explored mobile learning from different perspectives, such as adoption and application, feasibility studies of mobile learning implementation, split-attention and redundancy effects in mobile learning, prospects and challenges of mobile learning, adequacy and perceptions of m-learning, the impact of m-learning, and the meta-analysis of effects of mobile learning integration on learning performance. While these reports are interesting, our findings support an extension of novelty about the improvement of learning achievement with a mobile learning tool. As anticipated, the use of MobileEdu may have increased the accessibility of learning materials and students' learning activities based on results from previous studies (Jacob and Issac 2008). Besides, the flexibility of being able to use their mobile devices for educational purposes anytime, anywhere may have been advantageous (O'Bannon and Thomas 2015). The contextualized and individualized learning experience offered by MobileEdu could help students to organize and execute a learning routine even when they are not in front of a laptop. Nevertheless, further research is required to ascertain the impact of mobile learning on academic achievement, as the results of this study revealed *medium* effect-size learning achievement between the two groups.

Furthermore, the pedagogical experiences and attitudes of students using MobileEdu for computing education were considerably better than of students who did not use MobileEdu to support their learning. The item-by-item analysis of students' perceptions and attitudes toward computing education showed that for each item, there is an enhanced perception and attitude by experimental group learners. For example, on the first item, students in control group showed less acceptance of their interest in perceiving and analyzing the features of the system analysis and design course (Mean = 2.59 and SD = 1.44), while the experimental group indicated more interest (Mean = 4.57 and SD = 1.56), with a t-value of −7.87. The other items on students' perceptions and attitudes showed similar differences between the control and experimental groups. Consequently, we conclude that MobileEdu had a significant, positive impact on students' perceptions and attitudes. The results obtained are broadly consistent with the major trends about learners' perception and attitude regarding mobile learning especially with respect to increasing learners' interest in participating in learning activities, collaborating with peers, and increasing their learning motivation (Minjuan et al. 2009; Ozdamli and Uzunboylu 2015; Shonola et al. 2016; Oyelere et al. 2016b). Our analysis showed that the application of MobileEdu proved effective in improving the pedagogical experience of students. An item-by-item analysis of learners' pedagogical experience in the course also indicated that the experimental group had experiences that are more satisfying.

8 Conclusion and future work

First, we have reported the development process of MobileEdu—an android version of a mobile learning application. The motivation behind the all-inclusive mobile learning platform has been the lack of engagement due to a large number of learners in the Nigerian higher education context, affordability, and evolving nature of mobile technologies, and the creation of possibilities for learning computer science through a blended learning approach. Based on the identified challenges, we designed and implemented the first prototype of MobileEdu following the principles of JPDSR (Johannesson and Perjons 2014). The MobileEdu app facilitates blended learning, especially the library function where the teacher can upload videos, audios, animations, and texts of learning items (Hürst et al. 2007). The group function on MobileEdu will improve class management, learners' participation, and interactivity. The profile setup would enable the teacher to identify each student by name and picture, thereby helping to improve both the teachers' and students' self-esteem and involvement. Some other helpful functions allow students to interact easily with course materials, communicate effectively, socially interact, work in groups, and take quizzes (Alden 2013). The positive impacts of using mobile apps for learning have been identified by Leinonen et al. (2016), especially for blended learning, social learning, student-centered learning, and collaborative and project-based learning, all of which are supported in MobileEdu's implementation. Students can learn socially and collaboratively. The development and appraisal have provided feedback about the experiences of both instructors and learners after using the platform in the computer science course. Our research indicates that developing mobile learning applications through a well-established research method such as DSR is expedient because of its specific guidelines for evaluation and iteration.

Second, in the present study, we also evaluated MobileEdu and provided empirical evidence that enables an improved understanding of students' usage of the mobile learning environment. We not only examined learning the achievement of MobileEdu usage, but also attempted to investigate the learning experiences, perceptions, and attitudes among third-year undergraduate students participating in a one-semester course on system analysis and design. By analyzing students' learning achievements, experiences, and attitudes more closely, teachers and researchers can gain insights into how to best understand learners' mobile learning needs and determine how universities can support them. For example, the reason there is a lack of ubiquitous use of MobileEdu among users is likely due to their lack of experience with technology-driven learning, ingeniousness, and individual inability in using new technology. Hence, it might be necessary for more institutional support to offer students suitable preparation and opportunities to discover the potential advantages offered by new technology (Kang and Shin 2015). In addition, it is intuitive to ask whether the use of MobileEdu has a positive correlation with students' learning achievement, as mobile learning technology is extensively embraced in education, especially in developed countries, with the anticipation that it can have such a positive correlation. Nevertheless, several variables can influence learning achievement; hence, it may be challenging to confirm the overall influence of mobile devices and technology on learning. Therefore, this study attempted to develop a mobile learning system and investigated learners' experiences, thereby establishing the relationship between the use of a mobile learning system and learning achievement.

Based on the achievement of our investigation, we can conclude that MobileEdu has aided learners to obtain improved achievement from their learning activities. The mobile learning application proved to support learners, provide positive pedagogical experiences and improve their learning attitudes toward computing education. The findings suggest that this approach could also be useful and extended to other computing education areas, such as programming, algorithms, operating systems, and software engineering. Concerning these empirical results, this research expanded our understanding of how to develop and integrate mobile learning applications into universities and the effects of their use on learning achievement.

From our experience in this study, we have identified the following difficulties and made recommendations to researchers, teachers, and practitioners about integration of mobile learning application into computing education settings. Although this study yields substantial implications for the improvement of guidelines to support mobile learning in universities, it also has shortcomings in terms of results generalization. Because the research was conducted in a Nigerian university where mobile learning technology is still in its early stages, the results may not be generalized to other countries' educational systems. Consequently, there is a need for further studies in different educational settings to further study mobile learning usage patterns. Additionally, we observed a lack of awareness regarding the efficiency and applicability of mobile learning in the university setting in Nigeria. In view of this, we hereby recommend that series of publicity actions should be organized to educate the students about mobile learning applications and other technology interventions in the education sector. In addition, there is inefficient use of mobility opportunities offered by mobile learning. Few learners using MobileEdu tend to wait until whenever they are in the classroom or on campus instead of completing their learning activities anywhere and anytime. It is assumed that the learners are too accustomed to the traditional, face-face education approach. Mobility ought to provide the capacity to direct and facilitate learners and teachers, especially since mobile learning is typically contextualized. It is imperative that education practitioners should support learners to transit gradually from the teacher-centered traditional approach to learner-centered, for example, through a blended learning approach. This study only focused on the effect of using a mobile learning application on learning achievement with a general view and did not specifically consider the mobile devices' features and tools and the amount of time spent by learners on their studies, all of which might have an impact on their learning achievement. Another challenge observed was the lack of technical support for users of MobileEdu and a shortage of contact opportunities between teachers and learners. As technologies play an important role in mobile learning, educational practitioners (i.e., researchers, teachers, and course designers) and consumers (i.e., students) should interact regularly to improve the system, especially as per the demand of learners and technological updates. We hereby recommend that educators should choose appropriate teaching strategies that will suit learners' settings and pedagogies. The continuous implementation of mobile learning systems according to the dynamism and evolving nature of mobile communication systems is required for future educational settings. Since the DSR process is cyclical, future work will include the refinement/improvement of the MobileEdu system in accordance with the achievement of our evaluation. MobileEdu has significant potential because we intend to have an application that supports a variety of learning objects, activities, and contextualization of computing education. Based on the promising findings presented in this paper, work on the expansion of MobileEdu is continuing and will be presented in future papers. The aspect of contextualized game-based learning is the next target of our work on MobileEdu expansion.

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