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**SOLOMON SUNDAY OYELERE**

**DESIGN AND DEVELOPMENT OF A MOBILE LEARNING  
SYSTEM FOR COMPUTER SCIENCE EDUCATION  
IN NIGERIAN HIGHER EDUCATION CONTEXT**



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## ABSTRACT

This research focuses on the development of a mobile learning system in the context of Nigerian higher education institution. Mobile learning is an important component of the digital-age educational sector, and plays a key role in ubiquitous learning. Similarly, mobile learning is an increasingly important area in computer science discipline. Although several definitions of the term mobile learning exist, in this research mobile learning refers to teaching and learning approach that employs wireless technologies and mobile devices to support access to learning resources, promotes student direct engagement and interaction regardless of time, place, and context. The changes experienced by mobile learning over the past decade remain unprecedented. However, practical development and contextualization of mobile learning systems are rather inadequate. Recent developments in mobile learning have heightened the need for a mobile learning application that will aid the pedagogy of several topics in computer science education. Moreover, developing countries such as Nigeria have a shortage of mobile learning environments. Therefore, this dissertation seeks to explain the development of mobile learning system for computer science education in Nigerian context. The study stimulates good practice and promotes theoretical underpinning of mobile learning. Part of the aim of this study is to develop an application that will support learning of computing courses on mobile devices and offer guiding principles for integrating mobile learning into mainstream education. This dissertation follows a design science research, with in-depth analysis of existing systems, development of a mobile learning application, MobileEdu, testing the application in concrete settings and evaluation of the system for state-of-the-art. After several initial exploratory studies and systematic literature survey, MobileEdu was developed to aid teaching and learning of computer science courses on mobile devices. The concrete settings for both demonstration and evalu-

ation of MobileEdu are mainly Nigerian Universities. Furthermore, the study applied both qualitative and quantitative methods to investigate whether the use of MobileEdu improved learning achievement, pedagogical experience, and students' attitude towards computer science education. The findings from the evaluation are encouraging, and indicate that MobileEdu aided improvement in learning achievement of students. Besides, students' pedagogical experience and attitudes towards computer science education were positive. Therefore, this study makes a major contribution to research on mobile learning by demonstrating a contextualized artifact. In addition, it offers a theoretical extension of work related to implementing successfully a mobile learning-supported computer science education.

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Joensuu, 29th November 2017  
Solomon Sunday Oyelere.

## LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on data presented in the following articles, referred to by the **Roman Numerals I-VII**.

- I **Oyelere S.S**, Suhonen J, Sutinen E. (2016). M-Learning: A new paradigm of learning ICT in Nigeria. *International Journal of Interactive Mobile Technologies*, 10:1 35-44.
- II **Oyelere S.S**, Suhonen J, Shonola S.A, Joy M.S. (2016). Discovering students mobile learning experiences in higher education in Nigeria. *In the IEEE Proceedings of Frontiers in Education Conference, Eire, PA, USA*, 1-7.
- III **Oyelere S.S**, Paliktzoglou V, Suhonen J. (2016). M-learning in Nigerian higher education: an experimental study with Edmodo. *International Journal of Social Media and Interactive Learning Environments*, 4:1 43–62.
- IV Shonola S.A, Joy M.S, **Oyelere S.S**, Suhonen, J. (2016). The impact of mobile devices for learning in higher education institutions: Nigerian universities case study. *International Journal of Modern Education and Computer Science*, 8:8 43-50.
- V Anohah E, **Oyelere S.S**, Suhonen J, Sutinen E. (2017). Trends of mobile learning in computing education from 2006 to 2014: A systematic review of research publications. *International Journal of Mobile and Blended Learning*, 9:1 16-33.
- VI **Oyelere S.S**, Suhonen J, Wajiga G.M, Sutinen E. (2017). Design, development, and evaluation of a mobile learning application for computing education. *Education and Information Technologies*, Springer online first version.
- VII **Oyelere S.S**, Suhonen J, Laine T.H. (2017). Integrating Parson’s programming puzzles into a game-based mobile learning application. *In the Proceedings of the 17th Koli Calling International Conference on Computing Education Research, ACM*, 158–162.

The articles have been included at the end of this dissertation with permission of their respective copyright holders.



## AUTHOR'S CONTRIBUTION

The publications selected in this dissertation are original research articles on design and development of a mobile learning application. The author was the main contributor to all the manuscripts except for article IV and V. For articles I-III,VI,VII the author has implemented the mobile learning application, conducted experiments to evaluate its use, collected research data, carried out analysis as well as interpretation of the results. The followings are detailed description of author's contributions in each of the article:

**Paper I:** I am the main author of this article, which focused on the overview of mobile learning in Nigeria context as a way of charting the research area. The data collection and analysis of this article was conducted by me. The first draft of the article was made by me, however, the co-authors were responsible for providing comments to improve the article and made contribution toward the final draft.

**Paper II:** I am the main author of this paper that is dedicated to discovering Nigerian university students' mobile learning experience and determining its influence on interest and motivation. I and author 2 designed the questionnaire. I administered the questionnaire in six universities across Nigeria and carried out data anyalysis and presentation of results. The first draft of the article was made by me, however, the co-authors were responsible for providing comments and made contribution toward the final draft.

**Paper III:** I am the main author of this article, which investigated the inclination of university students to the use of social media tools. The article also evaluated the learning experience of students that are using Edmodo, a social media-learning environment. All the authors participated in the design of data collection instruments. I administered the questionnaire to students at Modibbo Adama University of Technology, Nigeria. I was responsible for data analysis, interpretation and the presentation of results. The first draft of the article was made by me, however, the co-authors were responsible for providing comments to improve the article and made contribution toward the final draft.

**Paper IV:** I am the co-author of Paper IV in which an assessment of the impact of the use of mobile devices for learning in Nigerian university was conducted. The data gathering and presentation of results were made by the first and second authors. The first draft of the article was made by the first and second authors, while I and the fourth author were jointly responsible for providing comments for improving the article and drafting of the final manuscript.

**Paper V:** Paper V, which focused on literature survey of existing works related to mobile learning in computer science education was coauthored by me. I and the first author performed the literature identification, categorization, analysis of themes and presentation of the findings. Myself and the first author wrote the first draft and subsequent drafts were made by the effort of all the three authors.

**Paper VI:** I am the main author of article VI that addresses the first developmental cycle of MobileEdu. I conducted the process of analysis, design, and the implementation of MobileEdu. I also piloted an experiment to evaluate whether the use of the tool has supported the students to achieve better grade and performance. I made the data analysis, interpretation and presentation of results from the experiment. Myself and second author made the first draft of the manuscript, however, the other co-authors supported the research with comments in the subsequent drafts.

**Paper VII:** I am the main author of article VI, which focused on the integration of board game and Parson's programming puzzles to MobileEdu, to improve engagement, motivation, and interaction in the learning of programming. The idea of integrating Parson's puzzles into Ayo board game came from me, however, the co-authors provided support to realize the concept. I made the first draft and the co-authors provided comments and inputs to the final draft.

In all the articles, the co-operation with the co-authors has been noteworthy.



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# 1 INTRODUCTION

This study focuses on the design and development of a mobile learning application for computer science education in the Nigerian higher education context. The objective of the study is to seek better ways to use mobile devices as learning tools in computing education and to provide guidelines to successfully integrate mobile learning into mainstream education.

This study is very timely as mobile learning is gaining relevance across several fields of study [2], [13], [14], [16], and [201]. Hence, there is a need for computer science practitioners to take the lead by demonstrating the feasibility of developing a mobile learning system for several topics in computer science education, especially in a developing country like Nigeria [**Paper V**]. Mobile devices, especially mobile phones, smartphones, tablets, personal digital assistants, laptops, game consoles, portable media players, navigation systems, pocket computers, digital cameras, and electronic readers, have progressively metamorphosed into ordinary and essential components of daily life. Moreover, the affordability and availability of mobile devices have reduced the digital divide, creating opportunities for the technologies to have a transformative influence on learning in the digital age [1, 2].

Furthermore, people's lifestyles have changed because of widespread mobile technologies and devices. For instance, how people work, communicate, travel, interact, and share experiences have changed dramatically [3]. Throughout this dissertation, the term *mobile learning* denotes the practice of using wireless technologies and mobile devices to support the teaching and learning processes by increasing access to learning resources, promoting learning engagement, and enabling students to interact with learning content irrespective of time, location, and context.

The changes accompanying the mobile revolution have a magnifying effect on the individual's learning in society. Therefore, learning is considered as dealing with changes that occur in a person's life over a certain period of time. In addition, learning could be associated with the results of knowledge acquisition during a learning process. Furthermore, the word "learning" can also denote the interaction that takes place between an individual, his environment, and the learning material, leading to changes in behavior, attitude, skills, knowledge, and pedagogical achievement [55]. In this study, learning consists of the mental and physical activities that lead to the acquisition of skills and knowledge, especially those related to the computer science discipline, which are obtained through engagement and interactions facilitated by mobile devices.

In recent years, learning in higher institutions has been influenced by countless technologies and innovations. Textbooks and blackboards dominated the traditional face-to-face method of instruction. However, in the technological era, several hardware and software devices facilitate the process of knowledge acquisition. In

addition, the learning process is progressively enriched by recent trends in technological advancements in a manner that was impossible before the advent of technology. One of the most significant transitional elements for the learning process is the internet, which has paved the way for improved communication, thereby enhancing the learning experience. These technological advancements have made it possible for improvements in educational technology. An example is electronic learning, which utilizes computers and electronic technologies to access and support learning, and improves educational approaches to be more learner-centered [4]. Furthermore, the advent of electronic learning in the 20th century saw the gradual transition from traditional classroom learning to the use of mobile technologies and devices [5]. Today, mobile learning is fast becoming a key learning approach and is gaining increasing interest [6].

Along with this growth in mobile learning, however, there is increasing concern about its impact in developing countries, such as Nigeria. The most populous African country with over 190 million citizens [7], Nigeria has more than 239.5 million connected lines, of which 154.1 million were active in February 2017 [8]. That is, about 81% of Nigerians own an active mobile or landline connection. Nevertheless, from my personal experience in a Nigerian university, the use of mobile devices to support learning activities has yet to yield the expected impact. Most of the universities in Nigeria have yet to integrate mobile learning into mainstream teaching and learning processes. Moreover, its overcrowded classrooms has led to a lack of interaction and engagement with the learning content. Therefore, it has become imperative to investigate the reasons for these gaps and provide solutions to ameliorate the present lack of mobile learning implementation in Nigerian universities.

## 1.1 BACKGROUND AND MOTIVATION

Quite recently, considerable attention has been paid to computer science education in Nigeria. For example, Haruna [10] evaluated the position of computer science education in the Universal Basic Education (UBE) curriculum and outlined the problems and prospects of implementing the curriculum. Similarly, Danmole [11] identified the subject, "*Computer Studies ICT Age*," as compulsory in the UBE curriculum. The Nigerian educational system is typically comprised of levels from primary school to higher education (see Figure 1.1). The school level comprises nine years of compulsory basic education, which starts at age 6 and generally ends when the student is 15. During the nine years of school, computer studies is a compulsory subject taught across the curriculum. After the Junior School Certificate Examination, students proceed to either senior secondary school or technical college, or vocational and innovation enterprise institutions, which last for three years. Although not compulsory at this level, computer studies is a subject offered in senior second-

ary school, and a trade option in technical colleges and vocational institutions. The second phase of education comprises one to six years of university education, one to three years of college education, one to two years of polytechnic education or one year of technical college education. During this phase of education, computer science is offered as a study program (leading to a degree or diploma certificate) or as a subject of study (part of a study program). The higher education level comprises several degree programs, ranging from the postgraduate diploma to the master's and doctoral degrees. In addition to offering students computer science and information communication technology as a degree program, a computer science course is mandatory for all students in higher education.

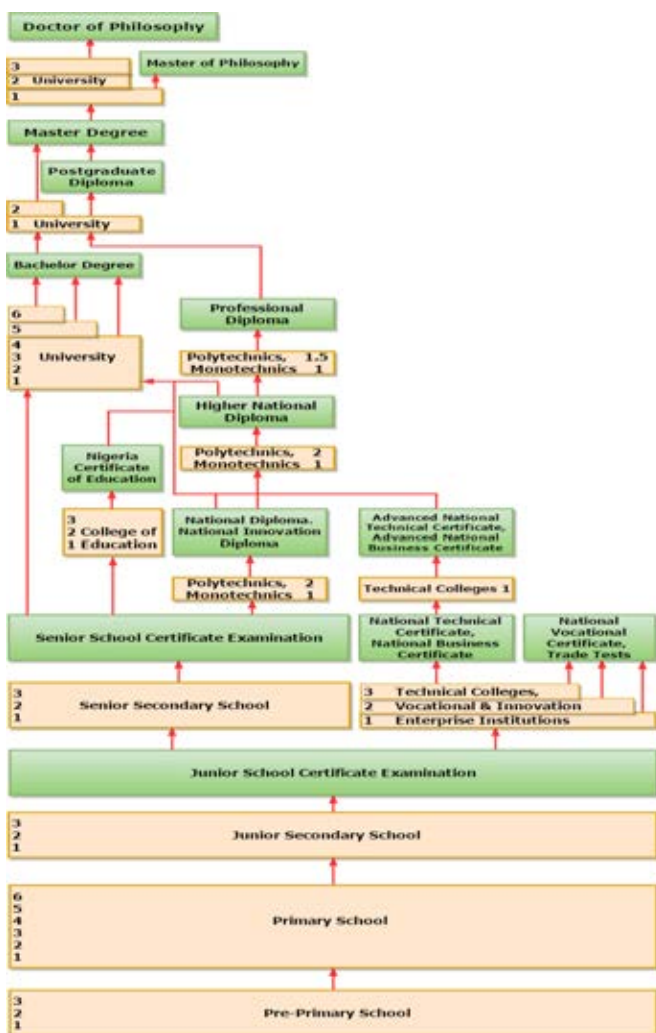


Figure 1.1. Nigerian Educational System (Adapted from <http://wenr.wes.org>).

However, several challenges face the field of computer science education in Nigeria. According to Haruna [10], these challenges range from an inadequate number of qualified teachers, a poor electricity supply, and poor implementation of computer science programs, to inadequate laboratories and equipment to support computer science education. To date, the traditional face-to-face teaching and learning method still plays a central role in the Nigerian educational context, and textbooks and blackboards are used on a daily basis to aid teaching. Even though the central government and different state governments have initiated programs to support the integration of information and communication technologies in the Nigerian educational system, few have yielded desired results. For example, the Osun state government introduced the “*School computer tablet*”,<sup>1</sup> a mobile learning initiative aimed at providing tablet computers to secondary school students [12]. A survey conducted about the ownership of mobile devices among Nigerian university students and teachers [13] showed that 91.8% of the students and 97.5% of the teachers uses mobile devices to engage in learning-related activities. The study also indicated that 24.1% of students and 66.3% of teachers have smartphones such as Android, iPhone, and Windows. Likewise, 48.2% of students and 90% of teachers already own laptops. Hence, both university students and teachers already possess mobile devices for learning. However, the teachers and students hardly use their own tools during classes. There could be many reasons for this, besides the lack of implementing a mobile learning system. Therefore, this study is relevant, as it breaks down the barrier of the lack of a mobile learning system to support computer science education in the Nigerian context. In addition, the study offers an exciting opportunity to provide a new perspective to understand mobile learning and to obtain information from users about the technological innovation.

Extensive research has been carried out and considerable attention has been paid to mobile learning globally. However, a gap remains in the development of a mobile learning application that will support the instruction of several topics in computer science education. Scholars have supported the fact that mobile technologies have unlimited possibilities to advance education [14-16]. The practical issue that motivated this study is the lack of direct interaction and engagement between teachers and students in computer science education. This issue is caused partly because of the large numbers of students currently in undergraduate classrooms in Nigerian universities.

## **1.2 RESEARCH QUESTIONS**

The research objective of the dissertation is to suggest guidelines for the integration of a mobile learning system into mainstream education in the context of developing countries. The focus of the research is divided into three main parts. First, the study

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<sup>1</sup> <http://osun.gov.ng/education/upon-imo>

aims to provide a broad assessment of the impact of mobile learning in Nigerian higher education, and an understanding of the trends of mobile learning studies in computer science education. Second, the study describes the activities related to the design, development, and experimentation of a new mobile learning system to support the teaching and learning of computer science curriculum. Third, the study evaluates the mobile learning system while providing guidelines on how to effectively integrate mobile learning into mainstream education. In particular, this dissertation will examine four main research questions:

**Research question 1:** What is the level of readiness and suitability of mobile learning to support computer science education in the context of Nigerian higher education institutions?

The mobile learning environment is considered to simplify access to learning resources in different contexts, and to engage students to learn on mobile devices anywhere anytime. However, the readiness of learners in computer science education towards the new technology is relevant for the successful integration and sustainability of the system. Furthermore, the suitability of devices, learning contexts, and learning environment to sustain computer science education is significant.

**Research question 2:** What are the key pedagogical features to implement in a mobile learning system to support learners and improve learning experiences in the context of Nigerian higher education institutions?

A need has arisen to identify and implement the relevant features of a typical mobile learning system based on existing theories, frameworks, and solutions in the Nigerian university context. The mobile learning system should support educators and students to connect, communicate, collaborate, share, and access learning on the go. These functions are essential for successful and meaningful learning to take place in any context.

**Research question 3:** Is there an improvement in students' learning achievements and attitudes after using a mobile learning system for computer science education in the context of Nigerian higher education institutions?

The principle of any system is to achieve reasonable success with its inner workings. Thus, since mobile learning systems are developed to support both teachers' and students' goals, it is appropriate to assess the level of results obtained after using the system. In addition, the perceptions and attitudes of students using the mobile learning system for computer science education are considered.

**Research question 4:** What kinds of guiding principles can be given to stakeholders in the context of Nigerian higher education institutions about mobile learning implementation and integration in computer science education?

Understanding and appreciating the application of technology-enhanced learning systems could be challenging and demanding not only for students and teachers but also the government, parents, and administrators. In practice, the integration process is multi-faceted and involves several domains of knowledge. This dissertation, therefore, provides the stakeholders (students, teachers, administrators, parents, and the government) in the context of Nigerian higher education institutions with guiding principles to support the implementation and integration of mobile learning into mainstream education.

### 1.3 RESEARCH METHODOLOGY AND PROCESS

This dissertation aims to answer questions related to the three main aspects of developing a mobile learning system: a broad assessment of mobile learning systems; the design and implementation of a mobile learning tool to support computer science education; and an evaluation of the mobile learning system. The focus of this research is the design and development of a mobile learning system for computer science education. As such, a pragmatic research approach, *design science research* (DSR), was selected for the research [17]. DSR consists of five main components. These include explicating the problem, outlining and defining the requirements, designing and developing the artifact, demonstrating the artifact, and evaluating the artifact. The entire DSR process is iterative and incremental, thus allowing the researcher to continuously redefine the goals and improve the outcome. Moreover, DSR is holistic in nature and has dual outcomes. First, an artifact should be developed that will solve a practical problem in a particular context. Second, DSR should increase the current knowledge base of the research area. Research strategies and creative methods are employed to provide answers to the questions in each of the DSR's components. Two major cycles of the research process were undertaken to arrive at the final artifact. During the first cycle, which covers **Paper I–VI**, we developed and evaluated the MobileEdu artifact based on the requirements presented by the teachers and students. The second cycle, which covers **Paper VII**, involved the integration of game-based learning and drag-and-drop programming tasks [93, 165] into the MobileEdu system.

DSR's problem explication component covers the aspects of **research questions 1 and 2** in the dissertation, in which the practical challenges that motivated the research are explored. A classical survey research approach was applied in **Paper I** to collect information and assess the readiness of a developing country, Nigeria, to embark on mobile learning. Items related to readiness and suitability, such as pos-



sessing the required infrastructure, ownership of mobile devices, and the ability to overcome challenges of mobile learning were surveyed. Mixed method research was adopted in **Papers II and IV**, which focused on determining the types of mobile devices used by students and exploring the factors affecting the adoption of mobile learning in Nigeria.

DSR's requirement definition component focuses on **Research question 2**, where the functional and non-functional requirements of the proposed system are underscored. On one hand, functional requirements describe the system's behavior in terms of functions, inputs, and outputs. On the other hand, non-functional requirements stipulate the general characteristics of the system such as reliability, performance, and cost. Classical education research, consisting of the application of either qualitative or quantitative methods depending on the research question being investigated, is used to conduct the research. A quantitative method expresses a post-positivist worldview, which, according to Popkewitz [18], should produce exact, unbiased, and value-free knowledge based on what can be observed and measured. In addition, qualitative methods reflect an interpretivistic (social constructivism) worldview or a subjective interpretation of reality – interpreting the experiences, opinions, and meanings of people [19]. Therefore, to answer **Research question 2**, we applied a mixed method approach [20] and the results were presented in **Paper III**. The mixed method approach involved the collection and analysis of data from several sources, which recognizes that each problem is addressed in a different manner. Additionally, the combination of research approaches in the study of the same phenomena, triangulation, offers more validity to the research results [19, 21]. Triangulation was achieved in this study by validating data from the questionnaires through interviews, observations, and a review of documents. The question that addresses eliciting the requirement for key pedagogical features expected of a mobile learning system are appropriately answered through qualitative research methods, since they deliver profound experiences, preferences, understandings, and interpretations of the people using the system. The qualitative research technique was used to gather information about students' perceptions of the different functions they deem suitable for mobile learning. The quantitative research technique aimed to systematically obtain empirical data from the students about mobile learning awareness, educational activities, and pedagogical functions of mobile devices.

DSR's design and develop artifact, demonstrate artifact, and evaluate artifact components are mainly dedicated to **Research question 3**. An artifact, MobileEdu – a mobile learning application, was developed according to the requirements identified in earlier DSR components. One experiment was conducted with 142 third-year undergraduate computer science students in a Nigerian university to evaluate the artifact in a real-life setting. During this experimental study, the investigator introduced a procedure and the outcome was observed. The aim of the experiment was

to answer **Research question 3**, which was to determine whether the learning achievements of students improved after using the mobile learning tool. A mixed method research approach was applied to examine the impact of the artifact on the pedagogical outcome of the students and to unravel their perceptions about the mobile learning tool. The results of this experiment are presented in **Papers VI and VII**. Quantitative research instruments such as pre-post quizzes and a feedback questionnaire were administered to the students to obtain data for the analysis. Pre-quizzes and post-quizzes have been used previously in research on the development of mobile learning systems for natural science courses (e.g., Chu et al. [22]). Similarly, the students' attitudes and learning experiences were evaluated by interviewing the students after using the artifact. The interviews were recorded, transcribed, and analyzed. The first stage of the interview analysis involved listening and reading the transcripts, coding relevant items, and creating code categories for further analysis. The coding process identified patterns of the perceptions, experiences, and attitudes towards MobileEdu, and how the students felt about the system.

To establish the guiding principles (**Research question 4**) that would foster the integration of mobile learning into mainstream education in Nigerian higher education institution contexts, the researcher adopted a literature survey and the experiences acquired through the process of conducting this research work.

With respect to ecological validity of the research, the empirical evaluations and experiments were completed in conditions in which the researcher had control, such as being the teacher during the classroom session when the experiment was conducted at the precise time of the students' learning. The results from this dissertation are ecologically tenable as they are obtained from real-life settings, and with the support of teachers, students, and laboratory technologists. Moreover, the experiment was conducted such that it could be replicated in other settings.

Table 1.1 shows how different research components of the DSR framework are connected to the research questions, research methods, and research papers. Similarly, Table 1.2 illustrates the research methods used in each article and the research questions addressed.

Table 1.1. The relationship between the research questions, DSR components, research methods, and research papers.

<b>Research question (RQ)</b>	<b>DSR component</b>	<b>Method</b>	<b>Paper</b>
RQ 1	Problem explication	Mixed method, literature survey	I, V
RQ 2	Requirement definition	Mixed method, experimental	II, III, IV
RQ 3	Design, develop, and demonstrate artifact	Mixed method, prototyping	VI, VII
RQ 4	Evaluate artifact	Mixed method, literature survey	VI

Table 1.2. The connection between the research papers, methods, and research questions.

Paper	Method	Research question (RQ)
I	Mixed method	RQ 1
II	Mixed method	RQ 2
III	Experimental, mixed method	RQ 2
IV	Mixed method	RQ 2
V	Literature survey	RQ 1, RQ 2
VI	Mixed method, literature survey	RQ 3, RQ 4
VII	Prototyping	RQ 3, RQ 4

## 1.4 THE MAIN RESULTS AND CONTRIBUTIONS

The main results of this study focus on the design, development, and evaluation of the mobile learning system, MobileEdu, for computer science education, and offers guidelines for the integration of mobile learning into mainstream education. The mobile learning system integrates several familiar learning functions and features that the students and teachers deem important for successful pedagogy. The research follows the pragmatic DSR framework, which led to two cycles of artifact development and evaluation.

The key results obtained from the evaluation of MobileEdu demonstrate that students benefit from using the tool in computer science education, as they are able to improve their learning engagement and achievements. Furthermore, the students' perceptions and attitudes towards computer science education were encouraging after using the mobile learning tool.

The research activities presented in this dissertation are a collection of seven papers published in several peer review academic forums such as journals and conference proceedings. The results from each of the seven papers are briefly summarized in the following paragraphs, and the papers are attached as an addendum to the dissertation.

**Paper I** presented an overview of the mobile learning field and the context of the study, Nigeria, by way of mapping the research territory. The study examined the prospects of mobile learning in Nigeria, and surveyed computer science education in Nigeria and its mobile infrastructure to ascertain the country's level of preparedness to implement mobile learning technology. The paper highlighted the benefits of mobile learning solutions to developing countries and identified several challenges that could militate mobile learning. The challenges identified were categorized into groups such as technical, security, social, pedagogical, and developing countries' peculiar challenges. Furthermore, the study assessed the availability of a mobile network infrastructure. The results indicated that the country's mobile infrastructure is capable of supporting mobile learning systems and that the students

already possess mobile devices. In addition, the study identified examples of mobile learning solutions that are suitable for computer science education, such as mobile games for programming, programming directly on mobile devices, teaching programming languages with mobile devices, and scaffolding construction of programs. Finally, the study indicated that students are ready to commence mobile learning and identified features that are supported, such as social media, push notifications, learning assessments, and progress monitoring functions.

**Paper II** focused mainly on discovering the students' mobile learning experiences in Nigerian universities. The study investigated the types of mobile devices owned by the students, determined the impact and experiences of using mobile devices for learning, and identified the factors affecting the adoption of mobile learning in Nigeria. The results indicated that the students use an array of devices, such as mobile phones, smartphones, tablets, personal digital assistants, pocket PCs, e-readers, and MP3 players. The results showed that features commonly used by students include emailing, social media, chatting, calls, texting, taking photos, videos, and gaming. The students expressed satisfaction with the potential of learning anywhere anytime and confirmed that mobile learning motivates their interest and inspires their learning.

**Paper III** was motivated by the findings from **Papers I and II**, based on the aspirations and yearning of students for social media features in mobile learning. The paper investigated the preference for social media tools among university students, and particularly evaluated the learning experience of students using a certain social media-learning environment, Edmodo. This study predominantly prepared the groundwork for our artifact by testing the effectiveness of the mobile learning environment in a real-life setting. The results from this study showed that the students' response to learning was improved and their eagerness to access social media sites through mobile devices was enhanced. The empirical results presented evidence that the social media function has a place in mobile learning environments.

**Paper IV** assessed the impact of mobile devices for learning in Nigerian universities by exploring the types of interactions students have with their mobile devices and identifying their willingness to use the devices for learning. The outcome from the study indicated that having course materials, such as slides, notes, and practice objects, on mobile devices makes learning easier and more flexible. Furthermore, the results showed that using mobile devices for learning has a significant impact on improving students' grades and performance.

**Paper V** presented the results of a systematic literature review related to mobile learning in computer science education. The results of the review revealed that mobile learning in computer science education has the potential to increase several affective traits of learners, and the field has matured to concern itself with the mainstream computer science curriculum. In addition, the study revealed that key aspects of mobile learning include mobile operating systems and technological fea-

tures, development platforms, subject areas, pedagogical approaches, learning effects, and the learner context. Furthermore, the study revealed that the Android mobile operating system is the most popular solution applied in mobile learning and reported several features that facilitate ubiquitous computer science education.

**Paper VI** addressed the first cycle developmental process of the mobile learning system under study and evaluated its use in a real-life setting as mandated by DSR. The paper highlighted the analysis, design, and implementation processes of the development of MobileEdu. An experiment was conducted to evaluate whether the using the tool supported the students to achieve better grades and performance. Furthermore, the study examined the impacts of using MobileEdu on the students' attitudes towards computer science education. The results showed that the tool helped the students to improve their learning achievements and pedagogical experiences. The study also offered suggestions for implementing mobile learning-supported computer science education.

**Paper VII** presented a new perspective on the implementation of a mobile learning solution through the integration of board games and Parson's programming puzzles [165, 166, 167, 170]. According to Ihantola and Karavirta [166], "Parson's programming puzzles are a family of code construction assignments where lines of code are given, and the task is to form the solution by sorting and possibly selecting the correct code lines." The study described the process of the development of a mobile application, which integrated puzzle-based Parson's programming exercises into a strategy board game and showed the mapping of the game to programming skills. The overall aim of the development was to provide a tool to facilitate the teaching and learning of programming on mobile computing devices. The expansion of MobileEdu is in line with the goal of the research and finding a solution to the problem that motivated the study: a lack of interactions, engagement, and motivation in computer science education in Nigeria.

## **1.5 ORGANIZATION OF THE DISSERTATION**

The rest of the dissertation is structured as follows: Chapter 2 introduces the concepts of mobile learning in computer science education. Also, related mobile learning theories are presented to buttress the theoretical underpinning of the dissertation. Chapter 3 presents the DSR framework in detail and illustrates the process of its application. Chapter 4 illustrates the first development cycle, steps, and activities undertaken to design, develop, and evaluate the mobile learning system. The chapter also presents the overall results of the study according to the research questions. Chapter 5 presents the second development cycle of the MobileEdu system and shows the steps taken to integrate Parson's puzzles into Ayo board game. Furthermore, several samples of the learning tasks were presented. Chapter 6 interprets the results and reflects on the implications of the findings by presenting the guiding

principles to support the integration of mobile learning into mainstream education in the Nigerian context. Chapter 7 summarizes the findings and offers recommendations for future research.

## 2 MOBILE LEARNING IN COMPUTER SCIENCE EDUCATION

### 2.1 COMPUTER SCIENCE EDUCATION IN THE NIGERIAN CONTEXT

Computer science education is a rapidly changing and progressively diverse academic field. The field is essentially tied to the application of software and hardware systems for teaching and learning computer science. These systems range from narrowly focused, teacher-implemented frameworks designed to support the students to learn a particular module to full-featured learning management systems such as Moodle<sup>2</sup> and Blackboard.<sup>3</sup> Computer science education has numerous features that are suitable for ubiquitous learning. Given the context of learning about computers, it is normal that many learning activities are accomplished and conveyed by means of computing devices. Consequently, several computer science courses integrate mobile learning, and many mobile learning environments have been developed for the field [23-27]. Moreover, familiarizing students with mobile applications in computer science education could help them establish a link between the learning content, the practical applications, and the devices they use daily [28]. Furthermore, assessments of learning activities and achievement are often done automatically nowadays, thereby supporting large numbers of students.

In the Nigerian context, computer science education remains an evolving field. The UBE curriculum of Nigeria mandates that every schoolchild must be taught computer studies and ICT [10, 11]. Therefore, the subject is taught across the elementary level of education in Nigeria. Similarly, at the upper basic education level, computer science courses are offered as a compulsory subject for all students of any major. Teachers are also trained to teach computer science at teacher training colleges and universities in Nigeria. Moreover, computer science education and ICT education can be studied from the bachelor to the doctoral degree levels in Nigerian universities. It is therefore vital to support the continuous development of this field in Nigeria.

### 2.2 MOBILE LEARNING IN THE AFRICAN CONTEXT

Mobile learning offers a wide-range of opportunities to enhance students' learning experiences and improve contemporary educational settings. Several authors have defined mobile learning in various ways, depending on what it meant to them at

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<sup>2</sup> <https://moodle.org/>

<sup>3</sup> <http://www.blackboard.com/>

the time. For example, according to Quinn in 2000, *“It’s e-learning through mobile computational devices: Palms, Windows CE machines, even your digital cell phone”* [29]. A decade later, precisely in 2010, Osman, El-Hussein, and Cronje defined mobile learning as *“any type of learning that takes place in learning environments and spaces that take account of the mobility of technology, mobility of learners, and mobility of learning”* [30]. More recently, in 2017, Xiao stated, *“. . . mobile learning involves the use of mobile technology, either alone or in combination with other information and communication technology (ICT), to enable learning anytime and anywhere”* [31].

Initial perspectives of mobile learning mainly focused on technology, individualism, and mobility [32], but presently, several diverse mobile learning perspectives exist, which basically focus on context, discipline-specific, or diverse features, and learner-centered, seamless, pervasive, and ubiquitous learning [33]. The perspective of this study is discipline-specific. Thus, mobile learning in computer science education is the use of wireless technologies and portable mobile computing devices to aid the process of teaching and learning computer science topics, such as system modelling, programming, problem solving, algorithms, etc., by increasing access to learning resources, enabling students’ learning experiences, promoting collaboration, engagement, and communication, and providing support for learning interactions. These supports enable learning anywhere anytime and for anyone. Mobile learning in computer science education occurs across diverse contexts, and offers flexibility to learners. For instance, according to Tillmann et al., *“instead of analyzing and manipulating abstract or teacher-provided data, students should write and execute programs on their own mobile devices, working with their own readily available content, making learning programming the engaging experience that it should be”* [34]. Hence, current mobile devices offer learners opportunities to obtain experiences, knowledge, and skills with great flexibility in diverse contexts.

It has been broadly acknowledged that context is the unique feature in mobile learning [3], [41], [58], [141]. Context in mobile learning characterizes the situation of a particular learner according to certain attributes, such as location, time, identity, physical environment information about mobile devices, localization, etc. Klopfer and Squire [197] illustrate the five properties of mobile devices – portability, social interactivity, context sensitivity, connectivity, and individuality – which provide a unique educational relevance. In addition, context-aware mobile learning applications leverage the context information of the student to deliver tailored and appealing learning experiences.

Several attempts have been made to develop a mobile learning framework for students in Nigeria. For example, the Jambmobile initiative reported in [13], the University of Ibadan initiative reported in [198], and the University of Ilorin initiative reported in [199] are initial efforts to implement mobile learning in Nigeria. Determined to implement mobile learning, the University of Ilorin in Nigeria provided tablet PCs to over 7,000 students matriculated for the 2013/2014 academic



session [199]. Similarly, a mobile learning framework, which was capable of enabling learners to access resources, submit assignments, and collaborate, was implemented at the Nnamdi Azikiwe University in Nigeria [200]. Although these attempts were steps in the right direction, several further efforts are necessary for mobile learning in Nigeria to gain the desired position in mainstream education. Moreover, mobile learning in the context of Nigerian higher education is still at an early stage, because of issues related to education in developing African countries, as outlined in [Paper I], [13], and [199].

The distribution of mobile learning-related studies across Africa showed that South Africa has the highest number of studies (11), followed by Nigeria (five), then Tanzania, Kenya, and Uganda with three each, Ghana and Botswana with two, and Mozambique, Zanzibar and Egypt each represented by one study [201]. The themes covered in the previous studies about mobile learning in Africa vary significantly. For example, some studies focused on the perceptions and acceptance of mobile learning by the teachers and students [202], [203], [204], and [205]. Findings from the study by Chang et al., [202] about the acceptance of mobile learning showed that eight major factors influence the readiness to adopt mobile learning in higher education in the developing African context. These factors are performance expectancy, facilitating conditions, environmental factors, technological, organizational, individual, and social influences, access, nature of the institution's leadership, and effort expectancy. Furthermore, the results indicated students' willingness to accept and use mobile learning systems if they were made particularly for learning. Similarly, findings from a study that investigated students' behavioral intention to adopt and use mobile learning in five higher education institutes in East Africa revealed four factors that have significant positive effects on students' mobile learning acceptance. These include performance expectancy, effort expectancy, social influence, and facilitating conditions. The performance expectancy shows the strongest predictor of students' behavioral intention to adopt mobile learning. The researchers argued that these findings would enable those who are involved in the implementation of mobile learning to develop mobile services that are relevant and acceptable to learners in higher education in East Africa [203].

Mobile learning studies in Africa have also focused on issues and challenges associated with implementation, such as [206], [207], [208], [209], [210], [211], and [212]. A survey conducted at three higher learning institutions in Zanzibar, Tanzania identified the following issues as reasons for the poor implementation of mobile learning: cost of mobile devices, poor technical support, poor physical infrastructure, low bandwidth, slow connectivity, and variations in mobile devices and technologies [207]. A similar study was conducted in Ghana, where the mobile learning tool AD-CONNECT was introduced in 44 courses with a total of 500 students and 22 lecturers at a college [208]. The teachers in the study expressed the following dissatisfaction with mobile learning:

- i. lack of familiarity with using a computer to develop teaching content;
- ii. lack of ownership of smartphones by some teachers;
- iii. the perception of some teachers that more time is needed to develop teaching content;
- iv. lack of motivation from university authorities to implement mobile learning;
- v. issues with intellectual property rights;
- vi. attitudinal issues;
- vii. pedagogical issues;
- viii. the cost of mobile broadband for the teacher;
- ix. the extension of working hours beyond the classroom with mobile learning providing 24-hour access to students;
- x. the lack of instructional design facilitators;
- xi. inadequate teaching assistants to assist lecturers on content development;
- xii. inconsistent internet connectivity at the university and at home;
- xiii. small smartphone keypads;
- xiv. the cost of a smartphone; and
- xv. the lack of a mobile learning policy in Ghana.

Based on these studies, it is evident that many higher education institutions in Africa are confronted with considerable challenges in implementing mobile learning.

Furthermore, previous studies have focused on the impact of mobile learning, and how mobile devices are used to enhance learning compared to traditional methods [208], [210], [213], [214], and [215]. Largely, the findings from these studies suggest that mobile devices can support various activities of learners, especially the following key categories of mobile device use were disclosed. These comprised: instant communication and collaboration between the learners and teachers; sharing and storing learning resources; flexibility and portability; support for experiential, self-directed, personalized, and authentic learning; availability and low cost of the technology; wider coverage; and minimized exclusion. For instance, a study at a South African university that focused on establishing how the use of mobile technology could enhance accessibility and communication in a blended learning course, showed that the students with access to mobile technology had a better prospect of accessing the courseware of the blended learning course. Furthermore, the same study disclosed that mobile technologies improved peer-to-peer communication among teachers and students with social networking applications [210].

Although the focus of this dissertation is mobile learning in computing education, the highlighted studies represent a general glimpse of the African context, considered significant to the overall implementation of this study. Furthermore,

Section 2.3 presents a global view of the underlying aspects of mobile learning design and implementation.

## **2.3 DESIGN AND IMPLEMENTATION PERSPECTIVES FOR MOBILE LEARNING IN COMPUTER SCIENCE EDUCATION**

In developing an instructional environment such as mobile learning, we deem it essential to consider the philosophical background, the different features that form the framework, and existing solutions to guide our development. Each of these gives different outlooks and practices for the design of a mobile learning system. Learning theories provide explanations of the complex processes involved in individuals acquiring skills and knowledge in various contexts [55]. Moreover, several features and characteristics are considered when designing a mobile learning system, which, when collected together, are referred to as a mobile learning framework. Examples of these characteristics are technology, learner, device, usability, content, pedagogy, context, social interaction, time, and culture [56], [57], [58]. These characteristics are relevant to the design of mobile learning because of its multi-faceted and changing attributes. Mobile learning goes beyond space, time, and place restrictions. Furthermore, to support and position our design, we considered several existing mobile learning solutions in computing education as sources of inspiration and technical guidance.

### **2.3.1 Learning theories**

According to cognitive psychologists, learning encompasses the use of memory, thinking, motivation, and reflection [35]. They suggest that learning, being an internal process, is hinged on the learners' processing capability, efforts, and depth of the processing of learning content. Contextualization of learning helps students to learn better. In addition, learners learn best when they derive personal meaning out of learning content and collaborate with other learners. Therefore, mobile learning supports personalized learning, since collaboration and anyone anywhere anytime learning permits learning contextualization [36].

There are many learning theories and mobile learning seems to have various theoretical viewpoints [32, 37, 38]. In fact, mobile learning theories originate from previous learning theories, such as behaviorism, cognitivism, connectivism, constructivism, situated learning, problem-based learning, context-aware learning, location-based learning, socio-cultural theory, lifelong learning, collaborative learning, conversational learning, informal learning, and activity theory [32, 38]. However, the current technology sphere holds a new premise and, therefore, past learning theories may not have profound applications in technology-enhanced environments such as mobile learning [39, 40]. Learning theories and ideas of learning have changed with time. The modern learning scenario tends to perceive learning as an

individual's pursuit of skills and knowledge with the teacher acting as a mere facilitator. This study will focus mainly on learning theories that have a strong connection and are often associated with computer science education and mobile learning, such as the behaviorist, cognitivist, constructivist, and connectivist theories. In addition, those learning theories are selected because they support the applied nature of most computing education topics, such as programming, algorithms, etc., and have the underlying principles to support learners on mobile devices in the digital era. Moreover, one can use different theories as a source of inspiration for designing and evaluating mobile learning solutions.

#### *2.3.1.1 Behaviorist learning theory*

Behaviorists focus on those activities that promote learning as a visible change in the observable actions of the student, and which are facilitated through the reinforcement of a specific stimulus and response [41, 42]. Reinforcement plays a vital role in meeting the learning expectations; hence, the learners tend to repeat a behavior that produces positive reinforcement. Relating this to computer science education, computer-aided learning is the presentation of a problem (stimulus) followed by the input on the part of the student of the solution (response) [41]. Feedback from the system then offers the reinforcement. Examples of the application of behaviorism in the context of mobile learning are quizzes or assessments for learning, video recordings, content delivery by text messages to mobile devices, classroom response systems, and practices.

#### *2.3.1.2 Cognitivist learning theory*

Cognitive learning theory and computer science education share the concepts of information processing to encompass the use of inner mental processes and memory. In fact, the computer science approach of memory storage and retrieval is considered analogous to cognitivists' belief that learning occurs through effective information organization and processing [43-45]. Knowledge acquisition is designated as a mental action, which necessitates internal coding and structuring by the student; consequently, the student is understood as a dynamic contributor in the learning process [46]. Since cognitive theories predominantly deal with mental structures, they are considered suitable for clarifying complex learning systems, such as information handling, problem solving, and reasoning. Information should be structured properly so that learners know how to connect novel ideas with prevailing information in a momentous style [46]. The focus of cognitive theory in mobile learning is on information and content delivery to support multimedia learning with the use of images, audio, video, text, animations, through mobile technologies such as SMS, MMS, e-mail, podcasting, and mobile TV [32].

### 2.3.1.3 Constructivist learning theory

Constructivism, a learner-centered approach, sets the learner in a flexible learning environment and activity process, in which learners construct their own meaning, and build new ideas and concepts based on current and previous knowledge, and content [47, 48]. According to Piaget [49], learners construct fresh knowledge from their experiences through the process of accommodation and assimilation. In computer science education, constructivists expect learners to discover knowledge individually and by themselves when placed in suitable conditions [50, 51]. Furthermore, learning occurs in realistic settings because constructivists consider environmental factors and rich learning experiences as essential for successful learning. They employ learning targeted at students' social interactions, collaboration, and realistic assessments [41, 52, 53]. Hence, students are stimulated to build knowledge while navigating in a real-life context and content-dependent mobile learning systems. A tool such as a mobile device supports communication, knowledge sharing, and speedy access to information, which is vital for learning.

### 2.3.1.4 Connectivist learning theory

Connectivism is considered the learning theory for the digital age. According to Siemens [54], "*connectivism is the integration of principles explored by chaos, network, and complexity and self-organization theories.*" It is focused on providing an understanding of the skills and tasks needed in a digital era. The core philosophies of connectivism recognize that learning and knowledge are situated in a diversity of opinions and may reside in non-human appliances such as mobile devices [54]. It also believes that nurturing and maintaining connections are desired to enable constant learning, for instance, through social networks [54]. Furthermore, the approach stresses the significance of information and relating it to precise individuals. Proficient information piloting and sifting are principally imperative [39, 54]. Hence, through mobile devices, students can access information and resources anytime anywhere.

## 2.3.2 Mobile learning frameworks

Mobile learning is innovative and forms an integral part of the future technological revolution of the educational sector. This section focuses attention on existing mobile learning frameworks that connect important mobile learning characteristics.

With theoretical foundations laid, most systems can be transferred into the operational environment through a robust framework. Mobile learning has come of age, and over the years, several frameworks have been formulated according to different perspectives, characteristics, and learning theories. Therefore, many schol-

ars have endeavored to capture the distinctive features of mobile learning into frameworks presented in Table 2.1 [55].

Table 2.1. Description of existing mobile learning frameworks adapted from [55]

<b>Author(s)</b>	<b>Underlying theory</b>	<b>Characteristics of the framework</b>	<b>Application</b>
Mostakhdemin-Hosseini, and Tuimala [57]	User studies, e-learning	Mobile usability, wireless technology, e-learning system	Development tool
Sharples et al. [58]	Cultural-historical activity theory	Technological layer, semiotic layer	Analysis tool
Motiwalla [5]	Constructive and conversational learning	Push and pull mechanisms, personalization, collaboration	Development tool
Parsons et al. [59]	Game representation	Generic mobile environment issues, learning context, learning experiences, learning objectives	Analysis tool, design tool
Liu et al. [60]	Action research	M-learning activity design, requirement and constraint analysis, mobile learning scenario design, mobile learning technology environment design, mobile learner support services design	Design tool
Koole [61]	Activity theory constructivism	Device aspect, learner aspect, social aspect, context of information	Guiding tool development and design tool
Park [62]	The transactional distance theory	Transactional distance, social nature of an activity	Analysis tool
Tan et al. [63]	Adaptive learning	Learner, location, time, content, device	Development tool
Issa et al. [64]	System criteria, just-in-time learning	The main system criteria, mobile devices, quality of services, application, and learners' requirements constraints	Analysis tool, development tool
Ozdamli [65]	Constructivism, blended learning, collaborative learning, and active learning	Integration of tools, pedagogical approaches, assessment techniques, teacher training	Guiding tool
Kearney et al. [66]	Socio-cultural perspective	Authenticity, collaboration, personalization, unique time-space contexts of mobile learning	Analysis tool, design tool
Sha et al. [67]	Self-regulated learning	Self-regulation as agency, mobile devices as social, cognitive, meta-cognitive tools, learning process as exercises of agency, social and pedagogical support for learner autonomy	Analysis tool
Wei and So [68]	Situated learner and contextual learning	External level (social, cultural, and technical factors), inter-medium level (content, context, and device) internal level (learner's attitude and experiences)	Evaluation tool
Ng and Nicholas [69]	Cisler's framework for sustainability of ICT in education	Relationship between technical aspects and people-related factors	Guiding tool
Prasertsilp [70]	Social constructivists theory, activity theory	Impacting factors, mobile learning environment	Design tool
Bensassi and Laroussi [71]	Dependability evaluation	Mobile learning activity, context, content, technical support, learning process	Evaluation tool
Scanlon et al. [72]	Incidental learning	Key elements are places, tasks, tools, social support, time, and learning journey	Analysis tool
Baloh et al. [73]	Self-study learning	The framework is used as self-study	Quality

			applications – applications that do not depend on the presence of a teacher	evaluation of mobile learning application
Stylianidis [74]	Flipped and case-based learning	case-	Content organization, content personalization, learning analytics, and educational gamification	Supports both design and delivery approaches of the learning design

Some of the presented frameworks are multifaceted and multi-level in nature, while others are single-sided, small, and simple. Similarly, the frameworks highlight diverse characteristics, tenacity, applications, and theoretical views. This is because mobile learning has several contextual applications; moreover, the field has focused on pilot studies about the users of the technology. These studies are mostly small-scale, temporary, and multidisciplinary, concentrating on users' attitudes, usage, perceptions, and acceptance. Obviously, this might have affected the integration of mobile learning into mainstream education. Although, the mobile learning frameworks presented in Table 2.1 show different features, important mobile learning concepts are commonly shared among the frameworks. Some of these shared features of mobile learning are learner/user, pedagogy/instruction, device, content, context, culture, and social interaction as maintained in [56].

### 2.3.3 Mobile learning solutions in computer science education

As explained in **Paper V**, much of the previous computing education research promotes mobile learning. The field also supports research in the development and use of several mobile learning tools. For example, computing education research has supported studies in the following different areas: i. Aspects of developing programming education tools, [24], [26], [28], [34], [94]; ii. Developing tools for learning data structures and algorithms [87]; iii. Developing tools for visualization and enhancing interactivity in programming education [90], [91]; and iv. Developing tools in other computing courses such as embedded system education [97], robotics [99], modeling, and specification [101]. Similarly, the field has begun discussing the integration of mobile application development into the computing curriculum [27]. Moreover, introducing learners to mobile applications and their development in computer science education is understood to support the learners to create connections between the learning content, practical applications, and the devices the learners use daily [76]. However, a knowledge gap exists about mobile learning solutions for computer science education, as identified in [75, 77]. The first issue relates to inadequate studies regarding the integration of mobile technologies into curricula. Second, unanimous agreement about the particular instructional design approaches to consider for implementing a computer science education mobile learning environment is lacking. In addition, the impact of mobile learning on vari-

ous cognitive variables, such as the cognitive, affective, and psychomotor domains of learners, has not been extensively studied [Paper V]. Therefore, several tools and solutions of mobile learning in computer science education are identified in Table 2.2. Some of these solutions have guided and motivated the mobile learning application under consideration in this study.

Table 2.2. Mobile learning tools for computer science education

<b>Tool and sources</b>	<b>Pedagogical solution</b>	<b>Output from real-life settings</b>
App Inventor [24, 26, 27, 78-83]	App Inventor is a visual programming environment for students to create an android application. It is an easy way to create applications for a mobile platform. It is designed to be handy and appealing to undergraduate non-majors taking introductory courses in computer science. Users can create mobile applications incorporating social networking, location awareness, and web-based services for Google's Android platform.	Used in several real-life settings such as students developing applications for healthcare, education, commerce, robotics, space, and technology.
TouchDevelop [25, 84, 85]	TouchDevelop is an application-creation environment aimed at aiding learners to develop applications directly on smartphones. TouchDevelop has a typed, structured programming language built around the idea of using only a touchscreen as the input device to author code.	Easy access to the rich sensor and personal data available on a mobile device results in a fun and engaging programming experience for students. Already used by high school students in a 9-week summer course developing games and applications with TouchDevelop.
Cabana [86]	Cabana is a web-based application designed to empower students to develop an application on multiple mobile platforms and to make application development easier. It supports the approach of JavaScript programming based on a wiring diagram.	Used in two courses: video game development and mobile application development. It is found to be useful in the classroom and recommended for use in both introductory courses and courses focused on high-level design.
Sortko [87]	Sortko is an Android-based smartphone application to support teaching of sorting algorithms.	The study discovered that students are motivated using technology for learning and the use of mobile devices prolonged learning.
H-SICAS [88]	H-SICAS is a handheld algorithm animation and simulation tool. The tool uses a procedural approach and supports the initial stages of programming learning.	Initial usability testing with teachers was positive.
WriteOn 1.0 [89]	WriteOn tool was developed to help teachers explain the materials during a classroom session through ink annotations on tablet devices. For example, explaining the functions of diverse coding blocks in a software engineering course.	The tool was tested in a classroom environment. WriteOn was used during the discussion of the simulation of simple software systems in the introduction to software engineering class.
mJeliot [90, 91]	In mJeliot, students can run and view visualizations of algorithm animations.	The experiment conducted showed that mobile media players have prospects of improving the learning of algorithms.
RoboLIFT [92]	RoboLIFT is a library that supports students' unit testing of Android applications.	The application supports existing automated grading techniques and sustains large student enrollments.



		It was used in a classroom setting for CS0 students with the aim of students learning how to test their solution code thoroughly. RoboLIFT supports basic interactions such as touching views, selecting menu items, and simulating keyboard input.
MobileParsons [93, 94]	MobileParsons is a Parsons problem-solving mobile learning application.	The MobileParsons solution extends the Parsons problem construction by minimizing the disadvantages of strict program scaffolding through creative coding exercises.
myVote [95]	myVote is a mobile-app-based collaborative learning system designed to support social interactions and encourage higher-order thinking skills.	myVote is used in three user scenarios: reinforcing students' understanding in an ad hoc style; eliciting knowledge, and promoting critical thinking.
Mobile game development [96]	The research describes a method of teaching a mobile game development course.	The course framework has been offered to students several times and is regularly progressing. The idea is to engage learners early in computer science through greatly motivating applications using mobile devices
NMMLA [23]	Native Mobile Multimedia Learning Application (NMMLA) Framework is a mobile learning environment designed to offer several courses on the Android platform. The framework supports learning objects such as Learn, Evaluate, Simulate, Resources, Chat, and e-Quiz.	The work will benefit students and teachers in the mobile learning field by providing a better learning and collaborative experience.
Android-based Mobile Sensory System Labware [97]	The work presents open source Android device-based labware to support learning of embedded system courses.	The labware facilitates practical, authentic, and creative learning experiences using smartphone devices with a Sensory microcontroller. Initial feedback from students is positive and encouraging.
mLo [98]	mLearning Objects (mLo) are interactive visualizations of program code examples or programming tasks. mLo was developed to aid students with comprehending programming structures effortlessly.	The project provided guidelines for the application of mobile learning objects in teaching and learning.
RoboRun [99]	In another example, mobile learning supports problem-based learning and games development for school students to learn programming.	The game platform allows touch input devices for coding, learning conditional programming, and algorithm sequence ordering.
MMLS [100]	Microlecture Mobile Learning System (MMLS) is a solution that helps students access videos, speech recognition, etc. to learn computer science courses.	MMLS links Microlecture with mobile learning to support pervasive learning. The results showed improvements in students' learning achievements.
BML-CO [101]	BML Context Oriented is an application that helps with the learning of requirements engineering on mobile devices.	The mobile learning helps to fill the gap of the arduous task of teaching requirements engineering.
NetLuke [102]	A mobile learning system to support the teaching of topics related to algorithms and data structure by visualization.	The tool supports direct data input by the user, the loading of existing visualization samples, and dynamic animations.

Program scaffolding mobile learning application [103]	A mobile learning tool to aid the learning of Java programming by five levels of scaffolding concepts.	The system was tested in the African context and showed a positive result for improving students' learning to program.
MobileEdu [Paper VI]	A mobile application that facilitates the learning of computer science courses on mobile devices.	The system was tested in real-life settings. The result shows good feedback from learners to improve interactions and engagement.

Visibly, a range of diverse pedagogical solutions are implemented and applied in computer science education to support flexibility, interactions, and active learning. Teaching practices and learning effects for mobile learning in computer science education are reported in our earlier studies [Paper V]. However, the current solutions were not premeditated for the African university context. Therefore, the dissertation described a mobile learning solution with a particular focus on the African context, but could be used in global educational scenarios as well. MobileEdu has been explicitly designed to ease the problems of poor engagement and interactions due to the enormous numbers of students in undergraduate computer science classrooms. In addition, the mobile learning application integrates several learning approaches and objects into one system, focusing on one discipline, and creates a new perspective into the growing research in the field of computer science education. An earlier study by Baran [105] maintained that researchers should shift their focus on research about the value of mobile learning to students, in order to concentrate on instituting theoretical and pedagogical frameworks and practices best suited for excellent mobile learning experiences. It is therefore important to develop and integrate a mobile learning system targeting a particular field, such as computer science education.

## 2.4 SUMMARY

This chapter has presented an overview of the field of mobile learning in computer science education, which forms the background of this dissertation. Researchers have tried to develop several mobile learning tools to support computer science education. Their goal was undoubtedly a valuable pursuit, to create a learning environment where students can learn anytime anywhere. In addition, Section 2.3.1 offered an overview of some learning theories that are related to mobile learning as a way of supporting the development of the MobileEdu system with theoretical backings. Furthermore, the theoretical foundations of the system are conveyed into the operational environment through the framework. Some relevant frameworks are highlighted in Section 2.3.2 to support the implementation of the solution. Finally, existing mobile learning solutions in the field of computer science education are revealed in Section 2.3.3. In this chapter, I have carefully chosen from different sources those theories, frameworks, and solutions that allow me to describe the

supposed benefits of MobileEdu implementation. The next chapter will focus on the research method adopted for the study.



## 3 RESEARCH APPROACH: DESIGN SCIENCE RESEARCH

The aim of this chapter is to describe the research approach applied in the process of developing a mobile learning solution for computer science education and to position the study within a pragmatic research approach, the *design science research* (DSR). Hence, the chapter gives a detailed description of the phases of DSR and shows its applicability in this work. Furthermore, the chapter demonstrates the DSR process through its rigorous iterative steps on the development of the MobileEdu artifact, bearing in mind the intent of the dissertation, which was to develop a mobile learning solution for computer science education. The solution was intended to solve learning issues arising from the lack of engagement and interactions in computer science classrooms in the developing country of Nigeria.

I chose DSR for this study because of its worth and suitable characteristics [106], [111], [112], [118], [119]:

- i. DSR addresses real-world problems in unique or innovative ways. Problems are solved more effectively and efficiently. The design produces new possibilities in the design context, and extends the existing knowledge related to the design knowledge. Learning programming on mobile devices is somewhat of a new concept, most especially in the developing African context, and this research extends knowledge in this regard;
- ii. DSR follows the process of investigation, planning, development, implementation, and creative evaluation steps. In this study, emphasis is given to the incremental and augmented process of activities;
- iii. Critical reflection leads to refining problems, solutions, and research methods during the process;
- iv. Outcomes of the DSR process should be transferable, practical, and generally liable;
- v. Experimental and incremental prototyping is one of the main methods to conduct experiments and draw knowledge from the prototypes;
- vi. Various design ideas are tested initially in practice, so that the design can be refined; and
- vii. Results and experiences of various evaluations can lead to re-designing or providing ideas for spin-off products.

### 3.1 DESIGN SCIENCE RESEARCH FRAMEWORK

DSR is a holistic method of problem solving through artifacts. It outlines a series of activities to accomplish and raise a set of questions to be answered through a sys-

tematic procedure [17]. One of the main drives of DSR is to support researchers to make explicit the design knowledge, by illuminating design principles and demonstrating a method for creating artifacts. This notion is supported by the definition given by Hevner and Chatterjee [106]:

*Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artifacts, thereby contributing new knowledge to the body of scientific evidence. The designed artifacts are both useful and fundamental in understanding that problem.*

The design and creation of the artifact is a collaborative assignment of both researchers and practitioners. The design starts with a precise assessment of the indigenous context; it is informed by consultation among relevant stakeholders, a review of relevant literature and relevant theory, and practice from other contexts; and it is designed explicitly to solve some problems or make an enhancement in a particular context [107]. DSR does not begin from a particular theoretical or methodological problem, but from the acknowledgement of a desire to change or improve something [108, 109]. According to Johannesson and Perjons [17], the practical problem of DSR can be motivated by, for example, a displeasing situation or a gap between the existing and a preferred state. The real-world problem can also be a baffling query, or an unforeseen occurrence, or a clearly recognized necessity for an adjustment or enhancement. In some circumstances, issues are not apparent until a fresh solution is hosted, which demonstrates that the existing practice can be enriched [110]. For instance, in our case, the problem of the lack of interactions and engagement in computer science education forms the basis for the study as described in [Paper VI], and [104]. The main goal is to develop a mobile learning solution for computer science education according to the needs, requirements, and expectations of students and teachers in the Nigerian higher education context.

The DSR procedure yields a number of outputs and interventions such as models, designed objects, methods, technological interventions, constructs, software applications, instantiations, social innovations, theories, and good practices [111-113]. For instance, design principles learnt in the course of the DSR process can be used to conduct and support the impending design efforts [114].

The development of an intervention and artifact is an important characteristic to show the outcome of DSR. Furthermore, to create an effective and results-oriented intervention with the aim of transforming learning with technologies, such as mobile learning, Jan et al. [115] identified the following design characteristics: “*frameworks for learning, the affordances of the chosen instructional tools, domain knowledge presentation, and contextual limitations.*” These design characteristics are tied to the context of our research, and the implemented intervention, MobileEdu, possesses

these four design characteristics. MobileEdu, as a framework for learning, is open to improvements and continuous refinements until precision is achieved.

Constant activities and interactions among the researchers occur throughout the DSR process, which are intended to improve the solution and the design process. Moreover, a better understanding of the issue and the resolution should both mend the quality of the output and improve the current knowledge of the design process [116, 117]. According to Akker et al. [118], educational design science focuses on the study of planning, designing, developing, and appraising learning programs, practices, procedures, and solutions to problems evolving from real-world settings. Similarly, the fundamental features of educational DSR are as follows. The first is to obtain general knowledge about the multifaceted learning problems in cooperation with students, teachers, and practitioners. Second, ascertain the most favorable features of the conceivable solution. Third, construct prototypes containing the favorable features. Fourth, experiment and evaluate the realized solutions in real-life settings. Finally, reflect on and refine the novel solution and possibly define fresh theories [119-121]. Therefore, the potential for DSR to promote concrete applicability of the use of technology in education are enormous and evolving.

In the context of this study, we adapted the DSR framework offered by Johansson and Perjons [17] in the design and development of the mobile learning solution for computer science education. Henceforth, the acronym *JPDSR* is used to denote their DSR framework. The *JPDSR* framework comprises the following processes (see Figure 3.1), which are iteratively and systematically connected to each other: explicate the problem; outline the artifact and define the requirements; design and develop the artifact; demonstrate the artifact; and finally, evaluate the artifact. In each phase of the *JPDSR*, a number of research strategies and methods may possibly apply to conduct the different activities, and all the activities can add to the knowledge base of the field under study and other areas closely related to the research.

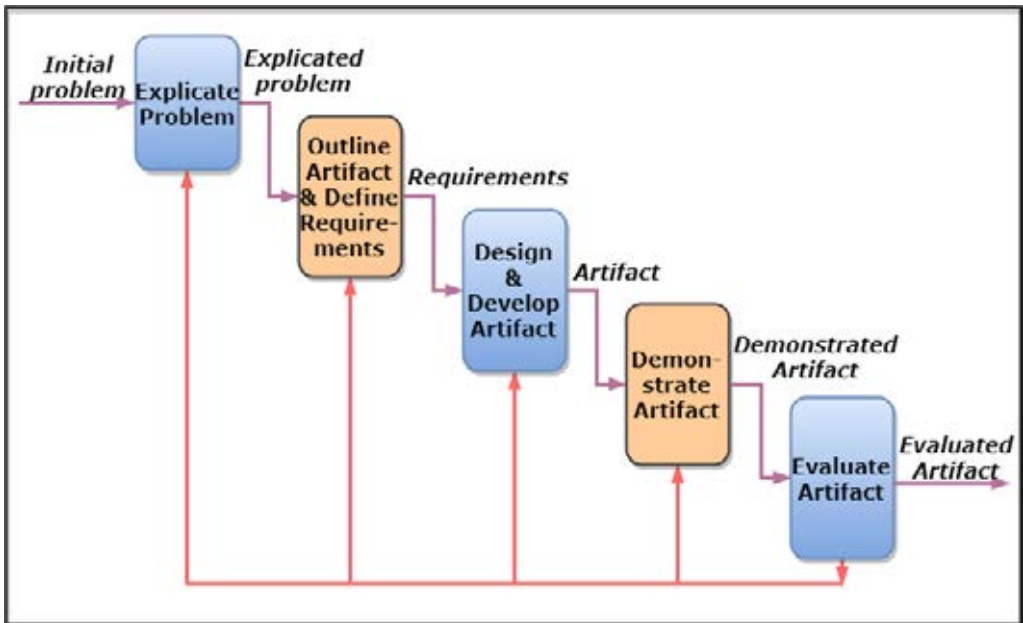


Figure 3.1. Initial illustration of the design science method redrawn from Johannesson and Perjons [17].

## 3.2 PHASES OF THE DESIGN SCIENCE RESEARCH FRAMEWORK

The DSR tasks can be enormous undertakings that involve several people, efforts, and an extended period of time [17, 122, 123]. Hence, the researchers and practitioners can take advantage of the numerous methods used in the DSR process to improve their research outputs.

### 3.2.1 Explicate the problem

The first activity in JPDSR is to *explicate the problem*, which is focused on exploring, evaluating, and dissecting a real-world problem. The implication is that the concrete problem behind the DSR process is to be unmistakably formulated and enthused by presenting it as important for some practice [17]. The problem should be shown to address general interest (i.e., not only substantial for one local practice), and may come from multiple sources [129]. In addition, fundamental reasons for the problem may be identified and examined. The core objectives of the problem explication phase are to elucidate the primary problem, situate it in the practice where it appears, articulate the problem accurately, and motivate the relevance of the problem to the community [118]. The fundamental problem that prompted this



research work was identified with the teachers and students, and rightly formulated after thorough analysis and preliminary investigation. The problem of the lack of engagement and interactions among computer science students in Nigerian universities was identified. The root cause of the problem is partly the large numbers of students in the classrooms.

### **3.2.2 Outline the artifact and define the requirements**

This activity enables the researcher to outline a solution to the identified problem in the appearance of an artifact. The step determines and sketches the requirements that form the metamorphosis of the problem into demands on the planned artifact [17]. Furthermore, the requirements are stipulated mainly for functionality, construction, and the environment. The aim is to express requirements and expectations according to the identified concrete problem. In addition, it commits to the conception of initial solutions to the explicated problem by transforming the requirements and opportunities into a well-designed solution [124]. In the case of our situation, the solution that was identified has a functional requirement of a mobile device-based system to support learners' interactions and engagement in computer science education.

### **3.2.3 Artifact design and development**

At this stage, an artifact is created, which solves the problem identified and realizes the requirements that were established in the previous DSR process. The artifact design mainly comprises determining the functionality of the solution and building the artifact [17]. Several design techniques are used in the process, such as participatory design approaches, rapid application development, agile design approaches, and dynamic systems development modelling principles. These methodologies are pertinent when converting the identified requirements into specifications, prototypes, and at the end, completely functional systems. After several trials with prototype development, the first version of the MobileEdu system was implemented successfully, and according to the requirements of enabling engagement and interactions among students and teachers in the computer science education settings in Nigerian universities.

### **3.2.4 Artifact demonstration**

To certify the solution and prove that it can solve the perceived problem, the *demonstrate the artifact* stage presents the first version of the solution to users in real-life settings or illustrative settings [124]. Furthermore, the feasibility and effectiveness of the implemented solution is analyzed at this point, as a show of proof-of-concept [17] that the artifact can solve the identified problem. The MobileEdu system was

demonstrated and used in real-world settings, where students and teachers had first-hand experience with the developed artifact.

### 3.2.5 Artifact evaluation

The last activity on the DSR framework involves the evaluation of the artifact to decide whether it satisfies the requirements and to what degree it resolves the problems, which forms the reason for its development. Several experimentation and testing schemes are used to conduct the evaluation to examine the impact of the solution [17, 125]. According to Venable, Pries-Heje, and Baskerville [126], evaluation of the artifacts and design theories is an important activity in DSR, because it offers feedback for additional improvements and guarantees the rigor of the research.

Formative evaluation is conducted early to gather feedback and improve the artifact, whereas summative evaluation is conducted to assess the overall impact of the artifact. The mixed methods research principle is particularly appropriate in the DSR process to integrate data describing characteristics (qualitative methods) and measurements or numerical analysis of data (quantitative) [127]. Similarly, the JPDSR process is iterative and permits the researcher to move back and forth between all stages of the DSR framework. Furthermore, as is typical of DSR to continue iteratively, which is analogous to the analysis-build-evaluate circle, it is naturally repeated a number of times to clarify the effectiveness of the solution, and then repeatedly review the solution according to results obtained from assessments in real-life settings [116, 128, 129]. The mobile learning system was developed through the iterative process required by DSR. In the course of using the MobileEdu system in real-world settings, experiments were conducted to evaluate and verify the effectiveness of the tool in addressing the problem of the lack of interactions and engagement among computer science education users. The results of the experiments and a further account of the study are presented in the subsequent section.

## 3.3 APPLICATION OF THE DESIGN SCIENCE RESEARCH FRAMEWORK IN THE RESEARCH AND DEVELOPMENT OF MOBILEEDU

Based on the iterative and incremental development principle of DSR, two design cycles were conducted during the development of MobileEdu. The first DSR design cycle of MobileEdu addressed **research questions 1 and 2** by identifying users' readiness, the suitability of mobile learning to support computer science education, and recognizing the main pedagogical features to implement in the mobile learning system to support learners and improve learning experiences. The second DSR design cycle of MobileEdu focused on the refinement and expansion of the learning environment, according to results obtained from the real-life setting experimenta-

tion and comments from users. Hence, **research question 3**, which evaluated the application and the relevance of the implemented mobile learning system to confirm whether students' learning achievements and attitudes improved after using the mobile learning system for computer science education, was answered. Furthermore, **research question 4**, which was centered on knowing whether the MobileEdu system has proffered a solution to the problem of low engagement, interactions, and motivation in computer science education, was answered. The JPDSR activities of the mobile learning solution are depicted in Figure 3.2. Similarly, the entire DSR process, showing the two cycles and dual outcomes of the research, is presented in Figure 3.3.

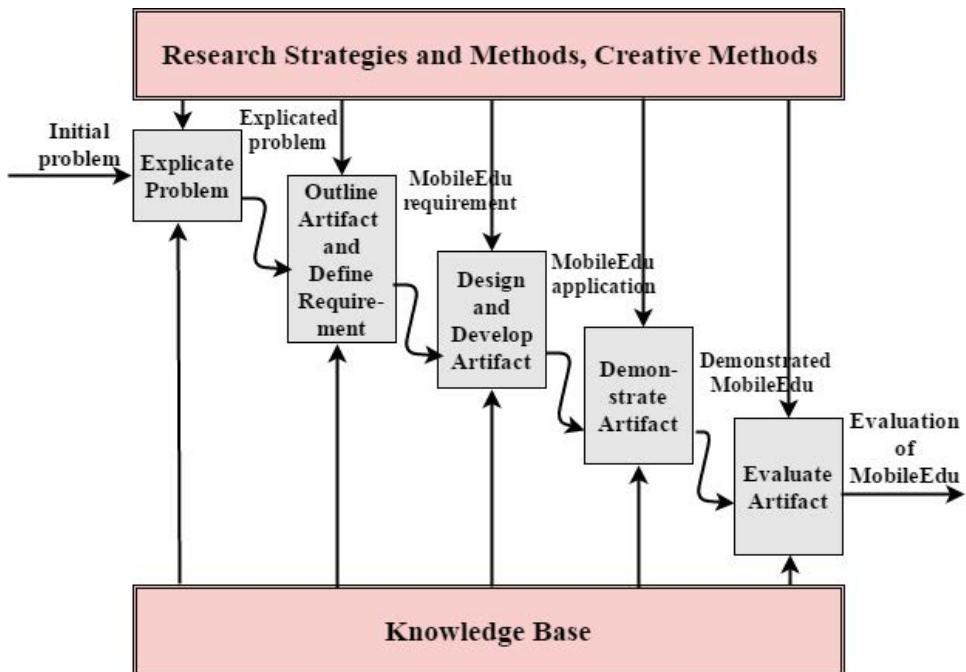


Figure 3.2. Design science research framework adapted from Johannesson and Perjons [17].

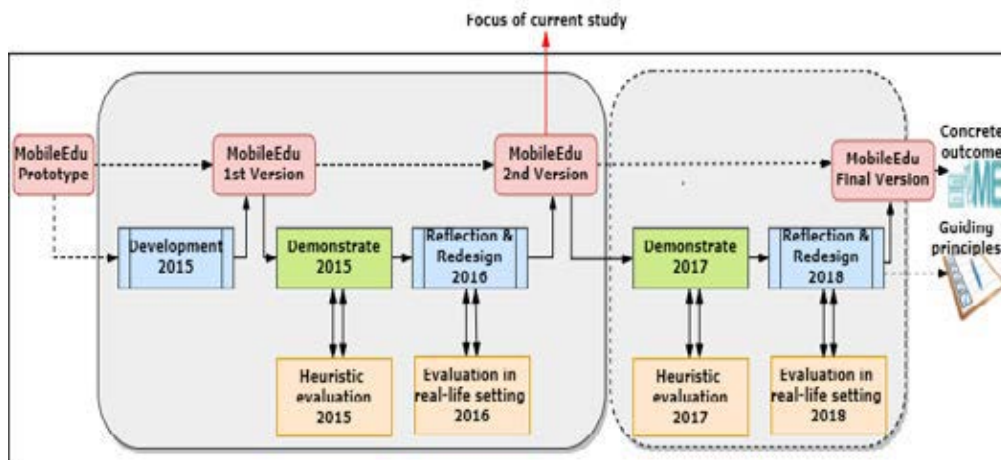


Figure 3.3. DSR process of MobileEdu showing two development cycles and dual outcomes (adapted from **Paper VII**).

### 3.4 SUMMARY

This chapter presented the DSR approach that was adopted for the study, and described the phases of DSR, which are used to accomplish the development of the mobile learning artifact. The DSR method, which is a holistic research approach of problem solving through artifacts, is comprised of problem explication, outlining the artifact and defining requirements, designing and developing the artifact, demonstrating the artifact, and evaluating the artifact. These phases are systematic, iterative, and incremental, thereby giving the researcher the opportunity to revisit and improve the solution at every step. In addition, the DSR phases were used to demonstrate the development of the mobile learning solution, MobileEdu, as presented in the next chapter.

## 4 FIRST DEVELOPMENT CYCLE OF MOBILEEDU

This chapter presents the results of the initial development cycle that culminated in the mobile learning environment, MobileEdu, to support computer science education. The collected works about computer science and mobile learning (see Chapter 2) show that several solutions exist for mobile learning, and the area has huge potential for future learning environments. However, several mobile learning concepts already exist, and diverse theoretical perspectives have been applied [55] in the global context. Nevertheless, developing African countries are still facing huge challenges with the implementation of mobile learning, especially for computing education. The real-world issue that drives this study emanates from my personal experience with teaching computer science at a Nigerian university. I observed that students do not adequately interact with the learning content. Moreover, engagement between teachers and students during programming education is insufficient. This issue is partly due to the large numbers of students enrolled in Nigerian universities that lack adequate infrastructures.

Several mobile learning-related approaches presented in Section 2.3 inspired the implementation of MobileEdu and form the theoretical background of this study. These learning approaches support the creation of a technology-enhanced learning environment, where learning computer science courses can successfully take place with the appropriate functional, significant, and pedagogical support for students and instructors, thereby improving motivation and students' learning experiences.

According to the literature examined in **Paper V**, particular emphasis is placed on the importance of harnessing mobile learning research by integrating mobile technologies in computer science education. Consequently, the DSR process was initiated after it was understood that a key gap existed in the mobile learning area, and a number of researchers underscored the need for a mobile learning framework for computer science education. For instance, [55], [62], [75], [130], [131] highlighted the need for researchers and instructional designers to continuously develop relevant theoretical frameworks for mobile learning and to provide direction for the effective integration of mobile devices in education.

### 4.1 EXPLICATE THE PROBLEM OF MOBILEEDU

There is need for prospective studies in educational technology to attract novel ideas in mobile learning and pedagogical practices. The real-life problem that inspired this research was the lack of direct interactions and engagement among teachers and students in computer science classrooms because of the large numbers

of students. From my experience, there is a massive number of student enrollments and a shortage of teachers in public universities in a developing country such as Nigeria [104], [Paper VI]. Hence, the teacher faces the issue of attending to hundreds of students in an undergraduate computer science class [104]. According to Kerr [132], the following problems are created due to overcrowded classrooms: i. Fewer number of direct contacts between teacher and student; ii. Poor organization of education undertakings; iii. Unsuccessful attainment of pedagogical objectives concerning higher order cognitive skills, such as analysis, synthesis, and application; iv. Poor morale, motivation, and confidence of learners and teachers; and v. Inadequate opportunities for specific feedback and student evaluation. However, the issues are common in education in developing countries, but they could be of universal interest.

The explication of the problem was conducted according to the following processes and resulted in **Papers I–IV**. Initial consultation was arranged among teachers, students, and administrators through discussions, interviews, and questionnaires. We explored students' readiness to adopt the use of mobile devices for computer science education, identified the student's particular mobile device preferences, and explored opinions regarding the suitability of mobile learning and the type of mobile learning solutions that suit learning computer science courses [9, 133, 134]. Successively, a systematic literature review was conducted to identify prevailing trends, technologies, and solutions, concerning mobile learning in computer science education [Paper V]. The literature review explored different perceptions on the integration of mobile learning into mainstream computer science education, such as technology and development, solutions and applications, and pedagogical principles and teaching approaches, to support mobile learning. Furthermore, the literature review motivated fine-tuning the mobile learning system requirements, and ultimately the design and development of the MobileEdu system.

The mobile phone revolution in Africa holds promise for mobile learning [135]. Mobile devices are reasonably more affordable than several other instructional tools, such as the laptop and PC. Besides, mobile learning has been advocated for both formal and informal education and to deliver knowledge and skills in developing countries [136]. According to Velghe [137], the acceptance of the mobile phone in Africa has improved interest in literacy and introduced new opportunities to communities that are deprived, marginalized, and less privileged. Similarly, Kafyulilo [138] wrote: ". . . 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). Hence, it was reasonable to exploit the affordability and large-scale ownership of mobile devices to develop a mobile learning system for the Nigerian higher education context. Furthermore, the study explored the concept of blended learning, which is a teaching approach that combines digital

media with traditional classroom techniques, especially to assist the instructor with teaching a large number of students [139, 140]. The researcher's desire was to design a mobile learning system to support blended learning rather than only the traditional face-to-face method. At present, the educational setting in Nigerian higher education is largely the traditional type, in which teachers and students are located in a certain confined setting. Although, the system has been useful for years, it may not be appropriate for the 21st century learning environment, where individualistic learning and student-centered learning are the norm. Moreover, the traditional system places high demands on teachers to cope with each student's needs without the aid of ICT tools, for instance, a mobile learning environment. Remodeling instruction to recognize the vital role of flexibility, networking, communication, mobility, teamwork, and collaboration, particularly for the mobile age, has been underscored [141]. Hence, it is relevant to recognize appropriate technologies to integrate into educational systems to solve the problems associated with learning environments. The teachers and students in Nigerian universities identified the need to improve the current learning environment by incorporating mobile devices into the mainstream educational system, since these devices are already widespread, affordable, easy to use, less bulky, culturally acceptable, and flexible.

## **4.2 OUTLINING THE INITIAL SOLUTION AND DEFINING THE REQUIREMENTS OF MOBILEEDU**

The key functional requirement for the mobile learning system is the capability to address the problem of a lack of interactions and engagement among teachers and students in computer science education [104], [Paper VI]. The large numbers of students pitted against the few teachers in Nigerian higher education settings add up to the problem. Teaching and learning in hugely populated classrooms is considered a basis for a decline in active engagement and teachers' interactions with their students [142]. According to Masita-Mwangi et al. [136], and Wang et al. [140], blended learning can increase engagement and improve learning performance. In order to increase engagement among teachers and students, Stanton and Ophoff [143] identified several communication functions; for example, push notifications, chat, email, discussion forums, and interactive self-practice materials. These functions support learners' engagement and increase their activity. Similarly, according to Al-Hmouz et al. [144], mobile technology enables teachers to share information in many ways that satisfies various student styles, including "*auditory (audio lectures), visual (diagrams, graphs), and linguistic (Word, PowerPoint), and a combination of these*" (p. 785). The opportunity to share information among students and teachers is vital for extending activities related to learning beyond the traditional classroom, and offering the much-desired flexibility, instantaneous access to learning materials, and contextualized learning experiences [145].

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 [146]. Alden, in [146], pointed out that the mobile learning system at Princeton University in New Jersey, USA, which was implemented in 2010, allows students to access learning notes in various formats, place announcements, post discussions, create learning content, attempt quizzes, and receive notifications. While we support these drives for mobile learning apps, it is also important to have state-of-the-art learning strategies to successfully develop mobile learning systems. Another requirement identified for the mobile learning system is to build a system that will support learners by conveying adapted learning content according to the learner's context, thereby creating an enriched learner model structure. To support the idea of a learner model structure, Al-Hmouz et al. [144] presented typical student scenarios:

*It is early Monday morning 8:00 am and Peter is going by bus/car/train from his flat to attend his lecture at the university which starts 8:30 am. Peter checks his PDA (3G network, 24 kbps bandwidth) to do some review to his lecture notes. Sara is in a restaurant for 20 minutes and wants to review her assessments using her smart phone (GSM network, 4 kbps bandwidth).*

*It is weekend and Mark is at home for an hour and wants to review his reading materials using his Nokia phone (3G network, 60 kbps bandwidth). (p. 784)*

The contextual elements, such as time, place, network, devices, current tasks, etc., in the above quote [144] indicate the types of learner activities at various points in time. Therefore, one requirement is for the mobile learning system to identify each user and his or her needs, such as a profile that represents the student and personalized learning activities. The next requirement is for the system to use devices to present learning materials, get reactions from learners, and offer proper feedback suitable for the Nigerian learning context. This is especially applicable to computer science education, where computer science topics, such as basic programming, demand repetitive drills, small chunks of tasks, and practice activities [41, 147]. Thus, a mobile learning system provides the benefits of tracking students' activities and progress, and adapting content and feedback to suit specific learning objectives and students. Social networking and blogging functions are identified as relevant solutions to mobile learning systems. In fact, the researcher conducted a survey to ascertain the pedagogical impact of a social media tool among computer science students in Nigerian universities [**Paper III**]. The outcome of the study indicated that students are familiar with social networking functions, such as chat and media sharing. The students admired the use of the social media tool for teamwork and collaboration activities. Therefore, social network functions, such as blog and chat, are notably important to the mobile learning environment. The following con-



cepts are leveraged in outlining the solutions and identifying the requirements: i. Advantages of the affordability of mobile devices in Africa; ii. The continuous improvement of mobile technologies; iii. The user acceptance of mobile devices; and iv. The support for ubiquitous learning. For example, a mobile learning system supports the contextualization of learning, access to lecture materials, and the use of input and output functions available on mobile devices, such as memory, GPS, camera, Bluetooth, sensors, multiple screens, microphone, audio, video, vibrator, touchscreen, mobile data, and Wi-Fi. According to Mostakhdemin-Hosseini and Tuimala [58], mobility, flexibility, social networking, and context awareness are essential learning functions for mobile-age students. Table 4.1 present a summary of the requirements that were identified by teachers, students, and myself during the elicitation stage [Paper III], [104], [Paper VI], and [Paper VII]:

Table 4.1. The system requirements and concrete functions associated with each requirement

Requirements	Concrete functions
Pedagogical requirements	This is focused on the learning aspects, such as content and resources, and student support, such as feedback, personalization of learning, collaboration, and context awareness
Technical requirements	These include a simple user interface, which is capable of easy navigation, a clear layout and well-organized features, easy accessibility of learning functions, support and usability
Connectivity and communication requirements	Several connectivity opportunities should be considered, easy communication on the system, possibility for roaming without network failure
Socio-cultural and economic requirements	These include local contents, cost of data, cheap smartphones
Security requirements	Protection of the device, contents, and persons using the system must be considered
Adaptation and expansion requirements	The system must be flexible, fast, capable of adapting to different plugins, and capable of expansion

An additional requirement satisfied by the mobile learning system under study is the prospect of supporting blended learning, which entails enabling students to access online digital media and carryout learning activities inside and outside the conventional classroom and in small groups [149].

The originality of MobileEdu lies in its ability to aid contextualized learning of computer science courses on mobile devices, and provide support to students in developing countries such as Nigeria. The design process of MobileEdu in the context of Nigeria is innovative. However, most of the attributes and functions outlined above are available on existing learning management systems, such as Moodle,<sup>4</sup> Blackboard,<sup>5</sup> and Edmodo.<sup>6</sup> These platforms were not originally designed as

<sup>4</sup> <https://moodle.org/>

<sup>5</sup> <http://www.blackboard.com>

<sup>6</sup> <https://www.edmodo.com/>

mobile applications. Although there are mobile versions of these platforms, some of the designs may not support the use of mobile device input and output features such as sensors (Bluetooth, GPS, etc.), cameras, gestures, and other contextualization features. These features are especially useful to ensure the smoothness of learning anywhere anytime. Features of mobile devices used in computing education are outlined in **Paper V**. In addition, a study conducted at Makerere University, Uganda, investigating university students' experiences with using a learning management system through mobile devices, showed that 53% of the respondents agreed that using the system on their mobile devices was frustrating [206]. The reasons given were that it was difficult to use the system on a mobile device, and much effort was required to navigate the learning management system on their mobile phones [206].

Moreover, it is necessary to implement a mobile learning application in the Nigerian context because most students can afford a mobile device but not all can afford a laptop. The idea of the MobileEdu app is not only for use in programming education but also other computer science courses, such as system analysis, design, algorithms, etc. To my knowledge, this first mobile app solution aims to provide features that support the learning of several computer science courses on mobile devices in Nigeria. Other existing solutions, which I outlined in Table 2.2, focused on specific topics or courses. No mobile app seems to exist that is dedicated to supporting all courses in computer science education. Hence, MobileEdu was developed to aid discipline-specific needs in computer science education course.

### **4.3 DESIGN AND DEVELOPMENT OF THE FIRST VERSION OF MOBILEEDU**

Several subsystems, infrastructures, and technologies are interconnected to achieve a complete mobile learning system. Based on the requirements and functionalities identified in Section 4.1.2, a prototyping design technique was adopted to design the initial system. Since the design of the artifact mainly comprises determining the functionality of the solution and building the artifact [17], a three-layer software architecture consisting of the mobile user infrastructure layer, the mobile protocol layer, and the database and server layer was constructed (see Figure 4.1).

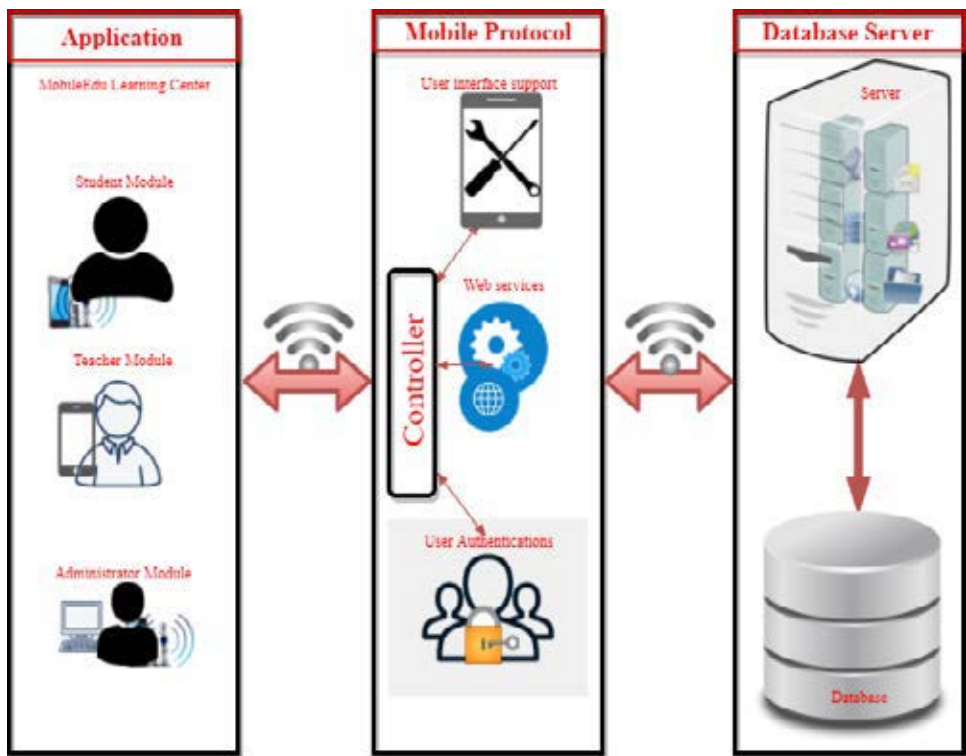


Figure 4.1. The three-layer MobileEdu system architecture.

The mobile user infrastructure subsystem, also referred to as the application layer, comprises the entire infrastructure required by the learner to successfully participate and achieve learning goals. Learners need an appropriate mobile device of any brand to access the system. Similarly, an accessible and uninterrupted wireless network, through either telecommunication mobile data or Wi-Fi, is vital. Coupling the identified system requirements and functional attributes, a physical structure comprising the learning center, the clients (users), the system administration panel, and the server was developed. The MobileEdu learning center is the heart of the entire system, and the sketches before prototyping are depicted in Figure 4.2 (a, b). The goal of the sketches in Figure 4.2 is to clearly present how the system will look to the user interface designer.



Figure 4.2a. Sketches of the system before prototyping.



Figure 4.2b. Sketches of the system before prototyping.

Table 4.2 presents the description of each of the tab on the application. Figure 4.3 represents a use case diagram displaying the actors and their roles in the MobileEdu system. After sketching the initial design of the application interface according to the outlined features and requirements, the earliest mockup prototype was developed as depicted in Figure 4.4 (a, b).

The System administrator panel is provided so the system administrator can manage users and the application. The administrator panel is web-based to run on any web browser. This aspect of the system was built on PHPMyAdmin, CSS, HTML, and Apache. The MobileEdu learning center is the core of the system. It is

comprised of eight tabs to achieve the requirements outlined for MobileEdu. Figure 4.5 (a–f) for sample interfaces of the application.

Table 4.2. Description of the tabs on MobileEdu

Tabs on the App	Description
My Class	supports various courses, user activities, such as selecting courses and identifying classmates for a 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 choosing 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	provides updates on upcoming activities

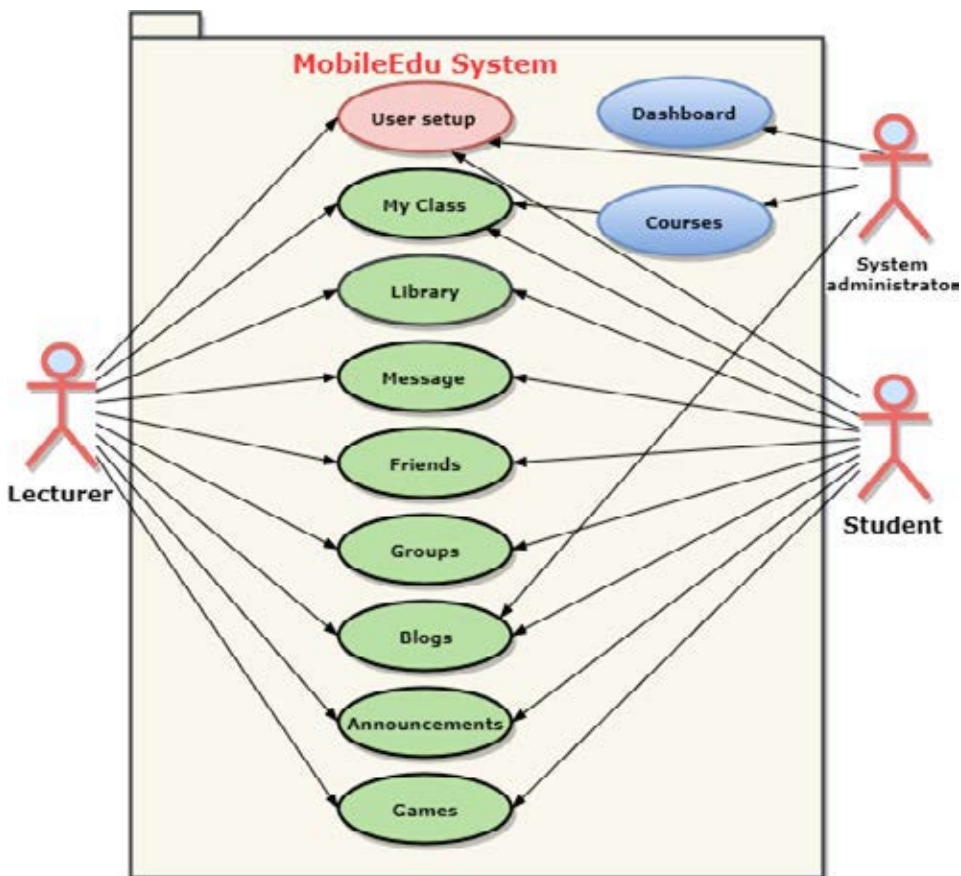


Figure 4.3. The use case model of MobileEdu system.



Figure 4.4a. Mockups of the initial prototype.

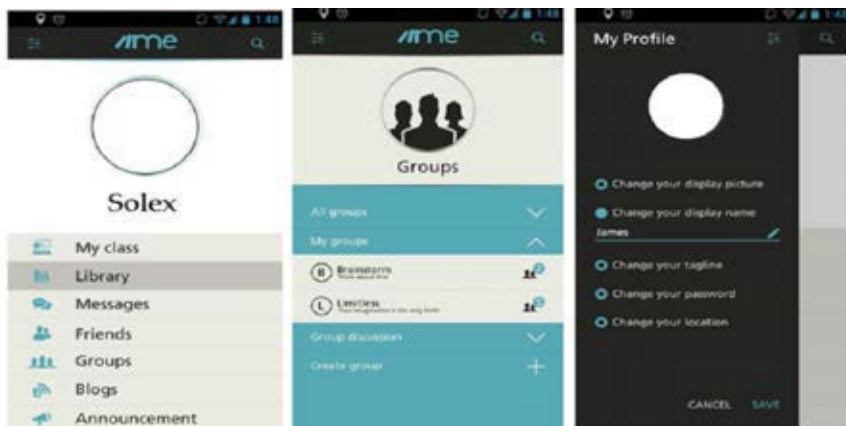


Figure 4.4b. Mockups of the initial prototype.

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 the *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 teachers' and learners' work, privacy, and the identification of learners. 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 their profile picture (an image or photo that depicts the user), display a name (a user's identification name), write a tagline (text related to the user), create a password (a secret key to access the platform), and show their location (the user's current position on the GPS).

The mobile protocol layer is also known as the core layer, which gives the application programming interfaces (APIs) access to the database layer, providing supports to user interfaces and web services. The mobile user nodes are connected to the mobile network infrastructure and operating system to give an identical interface to all devices at all times. The mobile protocol layer also enables access from the mobile user infrastructure layer to the database layer and gives rights to authentication. Mobility issues such as network reliability, quality of service, delays, transmission speed, and bandwidth fluxes are addressed at this layer. These issues, if not properly addressed, could result in poor performance of the mobile learning system, frustration of the users, and consequently, ending a learning period.

The database server layer is comprised of two components: database and server management services. The database subsystem provides storage for information collected on the mobile learning application. The database side was developed using an open-source relational database management system, MySQL. A server subsystem connects the clients' subsystem, learning center, database, and administrator subsystem. The server was implemented to serve as a bridge between the teacher and the student. On the server, modular and extensible web service-based architecture was used to export a range of APIs to users through client tools.



Figure 4.5a. Home screen after implementation



Figure 4.5b. Quiz screen

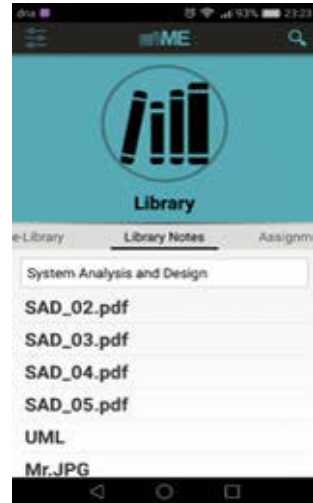


Figure 4.5c. Library tab showing files upload

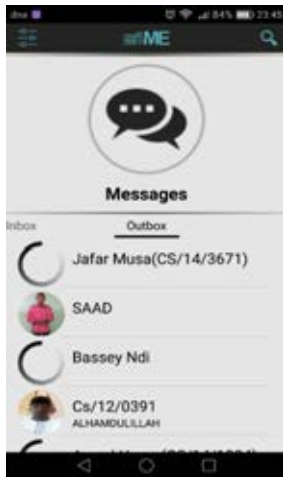


Figure 4.5d. Messages tab showing the outbox

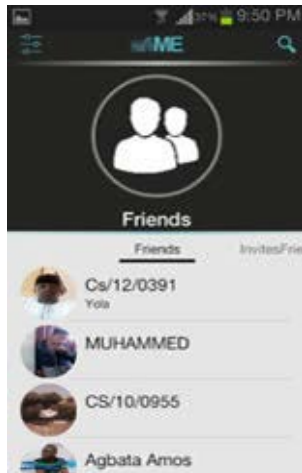


Figure 4.5e. Friends tab

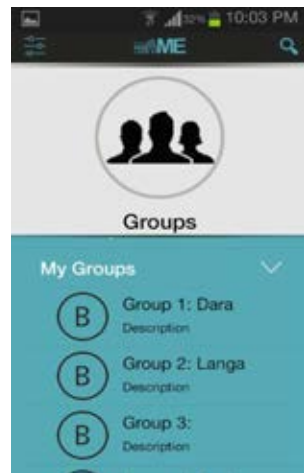


Figure 4.5f. Groups tab showing different groups for completing tasks



## 4.4 DEMONSTRATE AND EVALUATE THE FIRST VERSION OF MOBILEEDU

As a proof-of-concept and to certify the solution to solve the perceived problem, the first working version of the mobile learning system was presented. The system, termed MobileEdu, is an Android-based mobile application. To ensure the system's portability, efficiency, and maintainability, we built each subsystem using different software modules. After developing the application, it was tested on the emulator and real devices to check the functionality of the different components. Thereafter, the application was installed on real mobile devices for debugging. The testing was conducted on a 7.1-inch Samsung Galaxy S3 mini and 10.1-inch Samsung Galaxy tablet. The implemented artifact went through rigorous fine-tuning and iterations, as prescribed by DSR.

The last activity on the DSR framework is evaluating the mobile learning system to decide whether the artifact satisfies the requirements and to what degree it solves the problems that form the purpose for its development. In DSR, evaluation is mainly concerned with assessing the outputs [126, 150], including information systems design theories [151], and design artifacts [152]. The DSR framework for MobileEdu is illustrated in Figure 4.6.

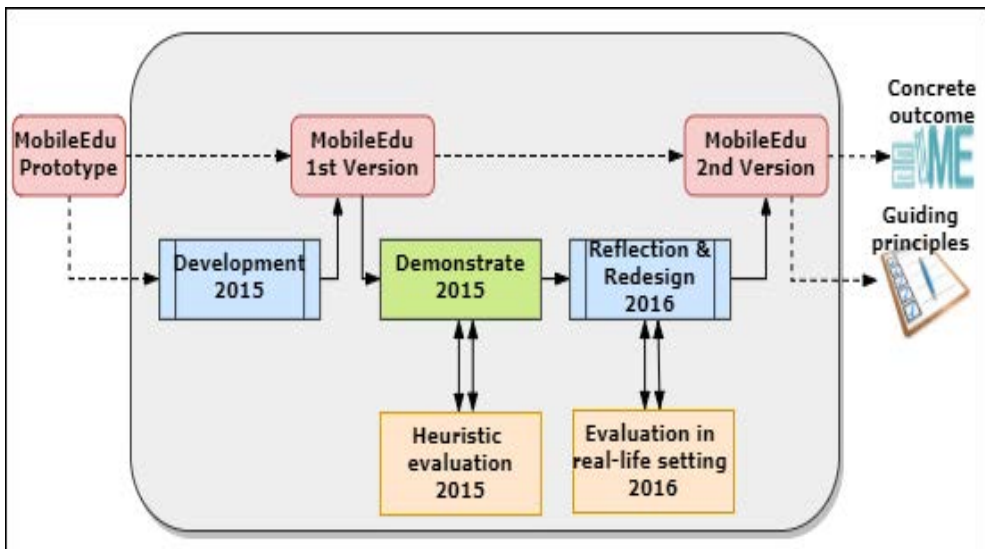


Figure 4.6. Summary of the DSR process of the initial design cycle of MobileEdu.

#### 4.4.1 Experimental design to evaluate the first version of MobileEdu

An experiment was conducted to evaluate the initial artifact with students and teachers in a real-life setting. The next paragraphs provide detailed information regarding the evaluation.

##### *Research context and participants in the study*

The study was piloted in the Department of Computer Science at the Modibbo Adama University of Technology Yola, Nigeria. The students recruited for the experiment were in their third year of an undergraduate computer science program and were participating in a system analysis and design course. There were 142 participants, who were divided into two groups for the purpose of the experiment. The control group comprised 71 students and the experimental group comprised 71 students as well. The students in the control group were only learning by the traditional face-to-face method. The students in the experimental group were learning entirely by the MobileEdu application.

Two expert evaluators and eight students in Nigeria higher education were recruited for the initial evaluation of the MobileEdu system. The evaluation identified a few bugs with respect to login interface, location awareness, student's task turn-in option, and the text display in blogs. The bugs were corrected and the system was ready for full evaluation. An experimental design was conducted to evaluate MobileEdu in real-life settings. The evaluation was to ascertain the feasibility, effectiveness, and suitability of MobileEdu in computer science education in the Nigerian higher education context. Furthermore, the experiment aimed to assess the viability of the mobile learning artifact, by confirming if students who learned through MobileEdu attained improved learning engagement and results, and had better pedagogical experiences than those who learned by following the traditional face-to-face method. Moreover, the experimental design evaluated the attitudes and perceptions of students about the tool. 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 teaching items 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, html), graphic and image processing formats (e.g., jpg, png), audio and sound file formats (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, communication, contextualization, and social networking. The course's slides, notes, short videos, and homework are 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. Details of the

experimental design and the results of this evaluation were subsequently presented in **Paper VI**.

*Learning activities during the study*

The experiment was conducted through a course of study, system analysis and design, which is a compulsory course in the computer science curriculum of Bachelor of Technology degrees in Nigerian universities. The course is mostly taught during one semester and is generally planned to offer contemporary systems development strategies, methodologies, tools, and practices. The content and schedule of activities in the course are illustrated in Table 4.3. In the first segment of the course's learning activities, the instructor divided the class into two groups (experimental and control), and then used one week to provide a guide to both groups separately about the fundamentals of systems analysis and a description of important terms in the course. In addition, both groups of students were separately enlightened about mobile learning and presented with guidelines about the use of MobileEdu. The awareness was intended to position all of the students on an equal level before the experiment [158]. I decided to introduce all of the students (both the control and the experimental group) to the MobileEdu user's guide to ensure that every student was given an opportunity to have an idea of the mobile learning tool, since it was probably the first time they were exposed to using such technology. Moreover, I envisaged that if I did not introduce mobile learning to all of the students at the same time, they might feel excluded. Furthermore, the general information was not considered influential in the experiment, since I wanted to ensure that all students were on an equal knowledge level. The full investigation procedure is depicted in Figure 4.7.

Table 4.3. The course content and schedule of learning activities (adapted from **Paper VI**)

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1st week: Introduction to MobileEdu, user guide tutorial, and introduction to system analysis course
2nd week: Systems development methodologies
3rd week: Understanding organizational systems for modeling
4th week: Fundamentals of IT project management
5th week: Information gathering & methods
6th week: Application of data flow 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

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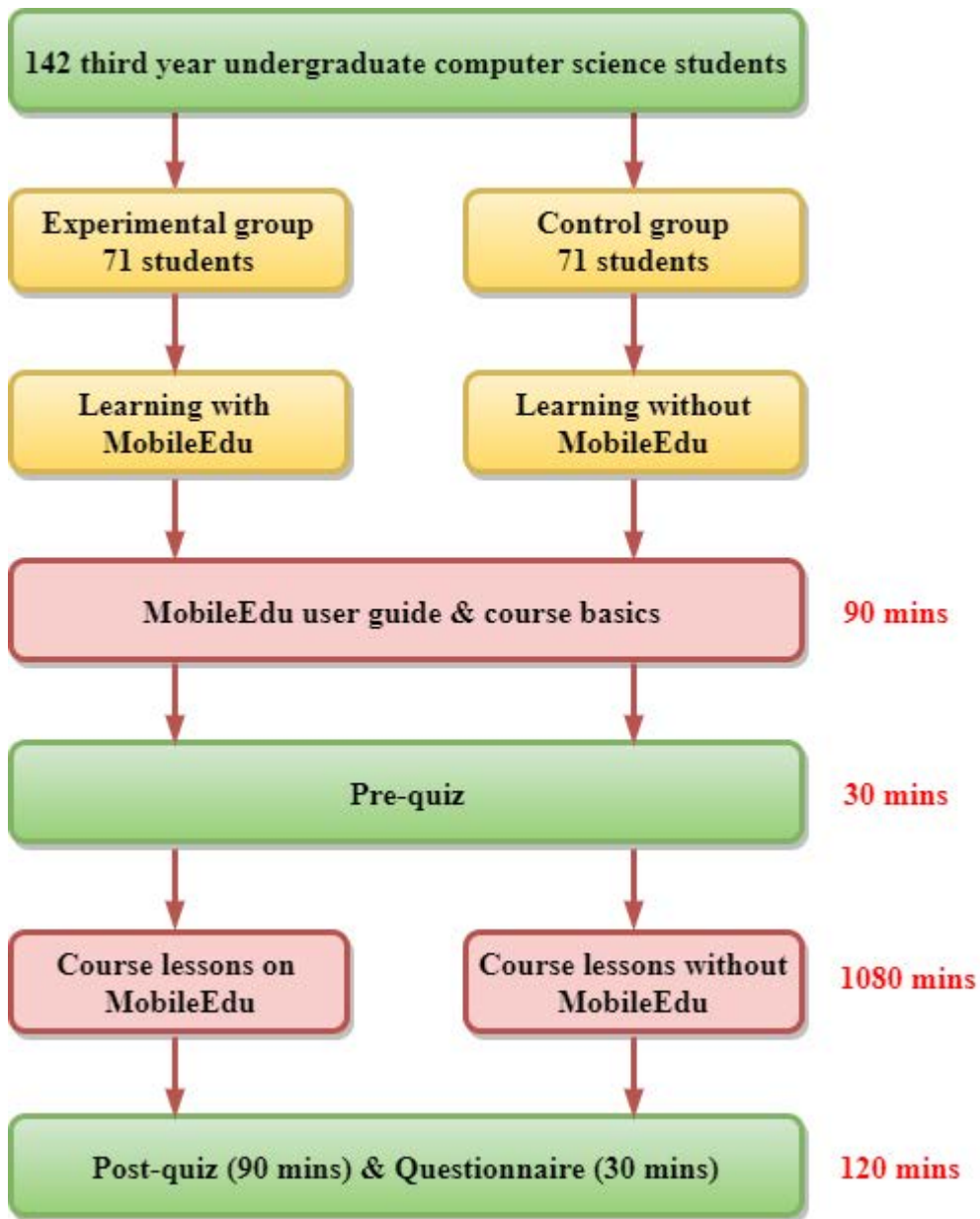


Figure 4.7. The full experimental procedure to evaluate the initial design of MobileEdu.

In the second segment, after giving the lesson on mobile learning and the course basics, a pre-quiz that lasted for 30 minutes was given to all participants. The quiz

was aimed at assessing the course fundamentals and determining whether the students were on the scale.

During the third segment, the main modules of the course were taught over a period of 12 weeks. The students in the control group only relied on traditional face-to-face instruction and class interactions. In contrast, the students in the experimental group relied on the MobileEdu application to learn and connect with their classmates virtually, anytime and anywhere. They also had opportunities to share knowledge, information, ideas, and educational materials outside school periods. Furthermore, the students in the experimental group could post questions to the teacher anytime and ask for assistance about unclear themes. After the completion of all course activities, which lasted for 13 weeks, the students attempted a post-quiz lasting 90 minutes and responded to a questionnaire that lasted for 30 minutes.

#### *Research instruments used in the study*

The data gathering instruments adopted for this experiment were pre-quiz, post-quiz, interviews, and questionnaires. The pre-quiz and post-quiz instruments were developed to assess the learning achievement of the students over the course periods. The purpose of the pre-quiz was to check whether the students in the control and experimental groups had equivalent basic knowledge of the system analysis course. Furthermore, the pre-quiz comprised 30 multiple-choice items obtained from the instructional materials. However, the post-quiz comprised 25 fill-in-the-blank items, 20 multiple-choice items, and 25 true-or-false items. The post-quiz covered all the themes in the course modules and focused on evaluating the students' understanding of the course. However, the questions in the quizzes were obtained from publishers of instructional materials, and three expert instructors were recruited to evaluate and validate the assessment items. Furthermore, 10 students participated in the individualized interviews, which were focused on obtaining their opinions about their experiences, perceptions, and attitudes on the use of MobileEdu for computer science education. Similarly, I administered a questionnaire, which lasted for 30 minutes, to all students in order to acquire information about their pedagogical experiences, perceptions, and attitudes in the course. The questionnaire comprised 10 items on a six-point Likert scale, where 1 represented strongly disagree and 6 represented strongly agree. The validity of the instruments was assured through the two experts who were engaged to review its contents. Therefore, the quiz and the questionnaire were decided according to the opinions of the experts.

#### *Research data analysis*

A mixture of both quantitative and qualitative methods was applied in the data analysis. The SPSS 21 software from IBM [154] aided in the analysis of the data. Throughout the data analysis, the means, standard deviations, and percentages

were determined. Similarly, t-tests and analysis of covariance (ANCOVA) were executed. A 95% confidence interval was used to interpret the data.

## 4.5 RESULTS FROM THE EVALUATION OF THE FIRST VERSION OF MOBILEEDU

### *The demography results*

The demographic results showed that 37% of the sampled respondents were female and 63% were male. The biggest age group that responded was 21–25 years (72%), followed by 26–30 years (22%), 31–35 years (3%), and 16–20 years (2%).

### *Results of the students' learning achievement*

In order to answer the research question (i.e., “Is there an improvement in students’ learning achievement and attitudes after using a mobile learning system for computer science education in the context of Nigerian higher education institutions?”), both pre- and post-quiz data were analyzed. The independent t-test was applied to analyze the pre-quiz data to confirm whether the students in the two groups had equivalent learning abilities after gaining the fundamental knowledge of the course. The results of the descriptive statistics are presented in Table 4.4.

Table 4.4. Descriptive statistics results of pre-quiz learning achievement (adapted from **Paper VI**)

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

Table 4.4 shows the t-test results obtained from the analysis of pre-quiz data. The t-test results revealed that there was no significant difference ( $t = 0.037$ , two-tailed  $p = 0.97$ ) between the control and experimental groups. This means that the two groups had statistically corresponding capabilities at the start of the course. An analysis of covariance (ANCOVA) was performed on post-quiz data and the results are presented in Table 4.5.

Table 4.5. Descriptive statistics and ANCOVA results for the post-quiz learning achievement (adapted from **Paper VI**)

Group of students		N	Mean	SD	Adjusted mean	F value	d
<b>Post-quiz</b>	Control	71	44.76	9.86	44.75	7.14*	0.59
	Experimental	71	50.65	9.93	50.65		

\*  $p < 0.001$

From the post-quiz learning achievement scores in Table 4.5, it is inferred that the average learning performance and achievement of the experimental group was significantly better than the students in the control group, ( $F = 7.14$ ,  $p < 0.001$ ). Additionally, effect size,  $d$ , which is a measure of the magnitude of the effect of a treatment between the two groups, was calculated. According to Cohen's benchmark [155], the effect size is defined as small,  $d = 0.2$ , medium,  $d = 0.5$ , and large,  $d = 0.8$ . In this study, the Cohen's  $d$  value of 0.59 indicates a medium effect size. The result indicates that the use of MobileEdu has aided in improving the learning achievement of students.

*Results about the pedagogical experiences, perceptions, and attitudes*

To answer the research question regarding the pedagogical experiences and attitudes of students who used MobileEdu for computer science education in a Nigerian university, both quantitative and qualitative methods were used to analyze the data. In the case of the quantitative approach, a questionnaire was used to collect the learners' experiences, perceptions, and attitudes about the course. The descriptive statistics outcomes obtained from the analysis of the questionnaire using a  $t$ -test are presented in Table 4.6 and Table 4.7.

The descriptive statistics results presented in Table 4.6 show differences between the two groups on each of the items in the questionnaire. The results in Table 4.7 show that the perceptions and attitudes of the students in the experimental group were significantly better ( $t = -15.45$ ,  $p < 0.0001$ ) than the students in the control group.

Table 4.6. Descriptive statistics results of each item on the questionnaire about students' perceptions and attitudes (adapted from **Paper VI**)

<b>Students' perceptions and attitudes</b>	<b>Control group (Mean/SD)</b>	<b>Experimental group (Mean/SD)</b>	<b>t</b>
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 a 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

$p < 0.0001$

Table 4.7. Descriptive statistics results of the questionnaire about students' perceptions and attitudes (adapted from **Paper VI**)

	Group of students	N	Mean	SD	t	p
Perceptions and attitudes (items 1–7)	Control	71	3.01	0.76	-15.45	< 0.0001
	Experimental	71	5.12	0.85		

Table 4.8 shows the results of the t-test analysis of the students' pedagogical experience items. The descriptive statistics results showed differences between the two groups on each item about pedagogical experiences. The experimental group students indicated that they had a better learning experience in the course.

Table 4.8. Independent t-values on questionnaire items about students' experiences (adapted from **Paper VI**)

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

$p < 0.0001$

Table 4.9. Descriptive statistics results of questionnaire about students' experiences (adapted from **Paper VI**)

	Group of students	N	Mean	SD	t	p
Experience (items 8–10)	Control	71	4.51	1.40	-4.53	< 0.0001
	Experimental	71	5.34	0.65		

The pedagogical experiences of the experimental group were significantly better ( $t = -4.53$ ,  $p < 0.0001$ ), than the control group, as shown in Table 4.9. The use of the MobileEdu application was an effective way to improve students' learning experiences.

### *Results from the interviews*

In the case of the qualitative analysis, an in-depth personalized interview was piloted to determine the pedagogical experiences, perceptions, and attitudes about the mobile learning environment, MobileEdu. The first phase of the data analysis of the interview involved understanding the transcripts, labeling relevant items, deciding which codes were the most important, and creating categories. The coding process enabled the retrieval of important information about the students' experi-



ences, perceptions, and attitudes concerning MobileEdu. The second phase involved the formulation of the interview data for description and interpretation according to the experimental settings. As opined by Rubin and Rubin [156], the value of a study is recognized through identified themes and their correlation with the research questions. The themes identified in the interview analysis are presented in Table 4.10.

Table 4.10. Analysis of students' opinions regarding the MobileEdu learning environment (adapted from **Paper VI**)

Theme	Aspects	Example quotations
Improved learning achievements	Quick and easy information access	<i>"Overall, I felt using MobileEdu helped me to access learning materials anywhere anytime to study, thereby improving my test score."</i>
	Ubiquitous learning	<i>"It was entirely a new experience to engage with course notes. I could ask for support from peers about the course."</i>
	Communication with peers	<i>"My learning output has increased by the mobile learning application."</i>
	Increased engagement with learning materials and content sharing	<i>"It was entirely a new experience to engage with course notes. I could ask for support from peers about the course."</i>
	Use of application is convenient and allows flexibility	<i>"My learning output has increased by the mobile learning application."</i>
Personalized learning experience	Appreciation towards personal learning opportunity	<i>"I now learn at my pace, thus focusing on facts." "I perform better when I set my own goals and get feedback from the teacher."</i>
	The application offered a change from traditional face-to-face teaching to new digital, blended learning	<i>"As a substitute for sitting and listening to the lecturer, I was really involved and receiving direct experience."</i>
	MobileEdu matched students learning preferences, timing, and style	
Technical and usability issues	Problems with internet connectivity issues, poor network reception to download and upload files	<i>"I find it difficult to download the application from the Google Play store." "I had to uninstall and reinstall several times."</i>
	Cost of using the application	<i>"It is expensive to buy data for internet access."</i>
	Incompatibility of MobileEdu with operating systems other than Android	<i>"Slow internet connectivity makes it hard to access MobileEdu."</i>
Features of the application	Class, Library, Announcement, Blog, and Groups features received positive feedback	<i>"Groups tab is working well because when we are assigned into groups, we work together with peers successfully."</i>
	Students reported problems with Library tab	<i>"I can see my course mate and interact with them, and message a friend on MobileEdu."</i>
	Suggested features to the application: examination grading, educational games, and local educational contents	<i>"I like the announcement feature because I can see the teacher's notices about class activities, assignment, venues, and time-lines."</i>

		<i>"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 device."</i>
Perceptions and attitudes towards mobile learning application	<p>Learning materials and course contents were effectively organized to support learning</p> <p>Using the mobile learning application engaged students in pleasant experiences and enhanced their attitudes and perceptions towards learning</p> <p>Enhancement of teamwork and collaboration experience</p>	<p><i>"The Class tab helps to identify my courses easily and the Library tab aided us to access learning materials."</i></p> <p><i>"MobileEdu meets my expectations as a learning tool because I find it handy."</i></p> <p><i>"I enjoyed group chat with classmates."</i></p> <p><i>"Good for the teachers because it the fastest means of getting in touch with students."</i></p> <p><i>"I can see my colleagues' discussions and chats on the platform."</i></p>

#### **4.6 DISCUSSION OF THE RESULTS OBTAINED FROM THE EVALUATION OF THE FIRST VERSION OF MOBILEEDU**

This subsection focuses on the discussion regarding the outcome of the experiment conducted to evaluate the initial version of MobileEdu.

The purpose of the experiment was to evaluate MobileEdu. The study was focused not only on the potential of MobileEdu to improve students' learning achievements, but also their pedagogical experiences and attitudes. The study expects that students' familiarity and experience with the learning environment is vital to ensuring encouraging practices in computer science education. Consequently, the study examined the possibilities offered by MobileEdu and determined the students' perceptions.

The results from the experimental study indicated a significant improvement in the learning achievement of students after using MobileEdu. At the beginning of the study, all students had equal knowledge about the course fundamentals. An independent t-test was used to analyze the results of the pre-quiz achievements of the control and experimental groups, and the result showed that they did not differ statistically before the experiment.

Treatment was administered and a post-treatment test was conducted to ascertain the effect of the treatment between the two groups. The results of the analysis of the learning achievement scores showed that the experimental group performed better than the students in the control group. The outcome of the investigation is consistent with previous studies in this direction, in which it has been revealed that

the use of a mobile learning environment may improve students' learning performance [157, 158].

As envisaged, the use of the MobileEdu learning environment may have augmented and eased access to information and learning resources, and aided learning activities, which is consistent with the results in the studies by Jacob and Issac [159]. Moreover, the students attributed an increase in engagement with easy access to learning resources. In addition, the students enjoyed the flexibility offered from using mobile devices for didactic purposes anytime, anywhere, and this could possibly have been beneficial to improving their overall learning interactions, engagement, and experiences [160]. Moreover, the contextualized and tailored pedagogical experience that MobileEdu presented might have supported students with organizing and accomplishing a learning task, even when they had no access to a laptop or PC, thereby increasing their engagement with the learning content. However, there is a need for additional investigation to determine the effect of mobile learning on students' affective domains and learning achievements, since the outcome of this study indicated a medium effect-size impact on the learning achievements between the two groups.

Furthermore, the study revealed that the students' learning experiences and attitudes while using MobileEdu for computer science education were significantly encouraging compared to the students not using MobileEdu to support their learning. An analysis of the items about the students' perceptions and attitudes towards computer science education revealed improved perceptions, interactions, and attitudes for those in the experimental group. For instance, the first item, which sought the students' opinions about whether they were more interested in perceiving and analyzing the features of system analysis, those in the experimental group indicated more interest and acceptance (Mean = 4.57 and SD = 1.56), compared to the students in the control group (Mean = 2.59 and SD = 1.44) at a t-value of  $-7.87$ . Similarly, the remaining items about the students' perceptions and attitudes revealed comparable differences between the two groups. Hence, I concluded that the use of the MobileEdu system had a positive influence on the engagement, interactions, perceptions, and attitudes of the students. The outcomes of the study regarding the students' perceptions and attitudes about the use of a mobile learning tool are consistent with other studies in the field, particularly about improving their interest and motivation to participate in learning activities, collaborating with peers, and teamwork [161, 162]. Furthermore, I observed that the level of interaction and engagement with learning activities greatly increased over the period of usage of MobileEdu. The increase in the learning outcome could be attributed to the increase in the students' engagement with the learning content and the feedback received from the teacher. Similarly, I observed that the students who used MobileEdu interacted with their peers and the teacher. They were willing to pose questions, request help about unclear topics, and perform activities in groups. The positive attitudes and

experiences shown by the students during the study, indicated that the use of MobileEdu in computer science education proved effective for supporting students' learning experiences.

## **4.7 SUMMARY**

This section focused on the DSR development process of the initial version of the MobileEdu system, and provided detailed descriptions of the activities undertaken in each of the steps. The first development cycle identified and implemented the functional requirements of a mobile learning system, according to the stakeholders' needs. The system was leveraged on the mobile phone revolution in Africa, affordability, flexibility, and dynamism of mobile technologies to offer students the opportunity to learn on the go. The problem addressed by this intervention is the lack of interactions and engagement among teachers and students in computer science education because of the large numbers of students in Nigerian university classrooms. The results from the first design cycle indicated that students in the experimental group had good experiences while using the system and learning achievement was better than in the control group. Similarly, the system could be used in a blended learning scenario and to support social learning.

## 5 SECOND DEVELOPMENT CYCLE OF MOBILEEDU

The initial design cycle opened an interesting question of how to make the artifact relevant for teaching courses such as programming. The pragmatic research methodology of DSR mandated that researchers, students, and teachers work together in the process of developing interventions and artifacts. Consequently, the second DSR development cycle focused on using the reflection and evaluation results of the previous cycle to further expand and develop the mobile learning system. Thus, the aim was to answer **research question 3** and present a mobile learning application that will support the teaching of several topics in computer science education.

### 5.1 RE-EXPLICATION OF THE PROBLEM, OUTLINING THE SOLUTION, AND DEFINING THE REQUIREMENTS OF MOBILEEDU

The fundamental problem that prompted the development of MobileEdu was the lack of engagement and interactions among computer science students in Nigerian universities. The root cause of the problem is partly due to the large numbers of students in the classrooms. As outlined in Section 4.1, the MobileEdu intervention provided relief from this problem and offered an environment that improved the engagement and interactions among teachers and students. Hence, there is need for further improvements for a wider application of the system in computer science education. The students, researchers, and teachers identified the need for the system to accommodate programming since that is the bedrock of computer science education. Furthermore, apart from the already existing social interaction components of the system, equally important is the aspect of motivation created through games. Therefore, integrating programming education and games became apparent in the next round of development.

The main requirement in the expansion process of MobileEdu was the integration of programming concepts and games. These would address the aspect of increased motivation, engagement, and hands-on programming by students and improve interactions among teachers and students. Understanding the basic programming concepts, logic, and syntax is an important part of learning programming. Regrettably, learning to program is tough and many times unexciting for novices [163, 164]; therefore, it is often difficult to motivate and engage the learners. For instance, novice programmers probably focus on narrow ideas, lack conceptual modelling skills, and fail to integrate problem-solving skills relevant in programming [163]. Similarly, novices tend to forget to properly apply the programming language vocabulary, logic, syntax, semantics, and styles, and their motivation and

interest in programming course diminish [164]. Parsons programming puzzles [165] are one solution to improve motivation, interest, and engagement in practicing basic programming skills. Students are presented with pieces of program codes as a drill, and they are expected to build a working program by ordering and selecting. Parsons puzzles were initially intended to support the learning of programming syntax and logic through repetition, but they were later used to teach problem solving through algorithmic thinking [166], joined with visualization [167], and used to create examination problems [168], [169], [170]. An additional solution to improve learners' motivation by making learning to program more exciting and engaging is through the introduction of educational games [164]. Therefore, the requirement of the solution was the integration of Parsons puzzles with board games to improve students' interactions, engagement, and motivation towards computer science education.

## 5.2 DESIGN OF THE SECOND VERSION OF MOBILEEDU

The initial mobile learning system and subsystems were adopted for the new version. Based on the requirements and functionalities identified, a new tab called *Game* was integrated into the learning center (Figure 5.1 shows the Game tab on the home screen of MobileEdu). The Game tab implements a strategy board game from the *Mancala* family, the *Ayo* game (in the Yoruba language of Southwest Nigeria). *Ayo* originated in Africa over 3,000 years ago [171], having diverse names and methods of play around the world. Two players play the game with 12 bins arranged on a board in array-like rows facing each player. The *Ayo* board in the preliminary position has four seeds in each of the six array-like bins and 0 seeds in the players' store bin, as presented in Figure 5.2. A larger bin (store or home bin) that holds captured seeds is located at the end of each player's row. The goal of the game is for a player to capture all the bins on the board by means of capturing as many seeds as possible in each round. *Ayo* starts with a predefined amount of seeds (typically 4 or 6, subject to the game variant) in each player's bin and an empty store bin. Details of the rules, strategies, and play of the *Ayo* game are presented in [172, 173].

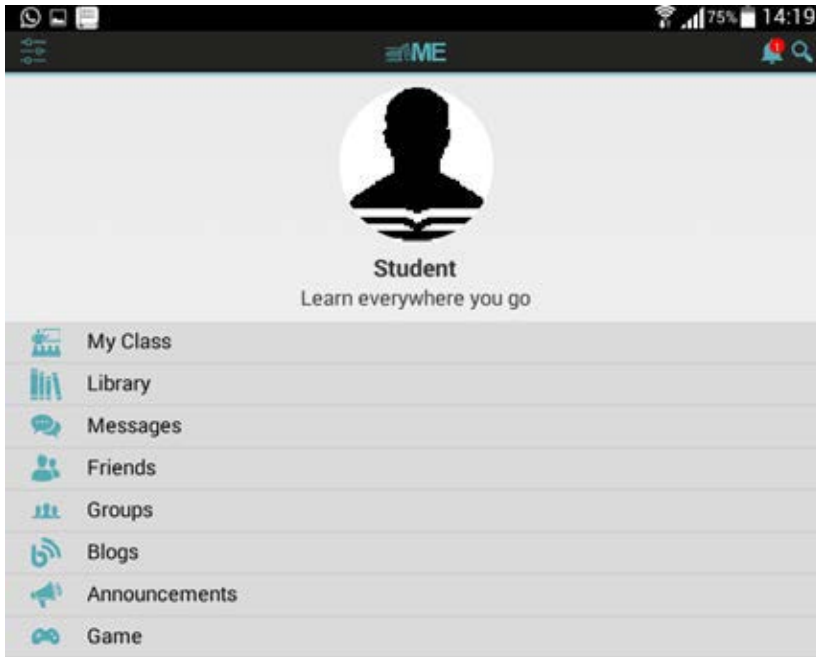


Figure 5.1. The Game tab shown on the MobileEdu Home screen.

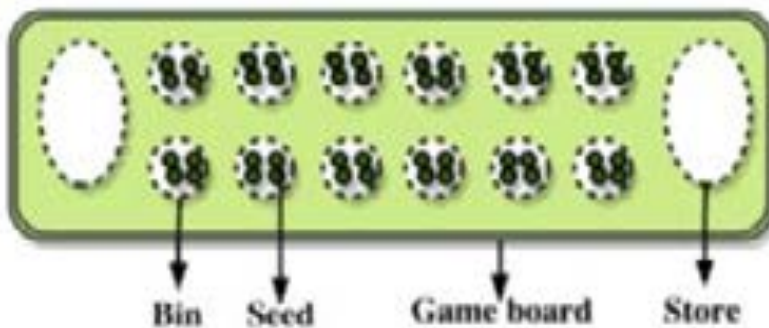


Figure 5.2. Ayo board in its initial position with four seeds in each of the six array-like bins and 0 seeds in the store bins (adapted from **Paper VII**).

When a learner taps the Game tab, four play modes are presented for selection (Figure 5.3). A player can choose: player versus the computer (one player); player versus another player on the same device (two player); player versus another player over Bluetooth (play Bluetooth); and player versus another player online (play online). The play Bluetooth option is contextually significant to developing countries, such as Nigeria, that are struggling with poor Wi-Fi and networking infrastruc-

tures [9, 133]. The students can play and learn on the game without an internet network connection. Playing online and Bluetooth must be setup through mutual agreement between the host and guest players (Figure 5.4 illustrates the Bluetooth setup screen). The Ayo game interface comprises the player's name, number of seeds captured, number of bins captured, and a seed-sowing counter, which decreases as seed dropping continues on each bin. The game board showing all the game features during two-player game session is presented in Figure 5.5.



Figure 5.3. Play mode selection screen (adapted from **Paper VII**).

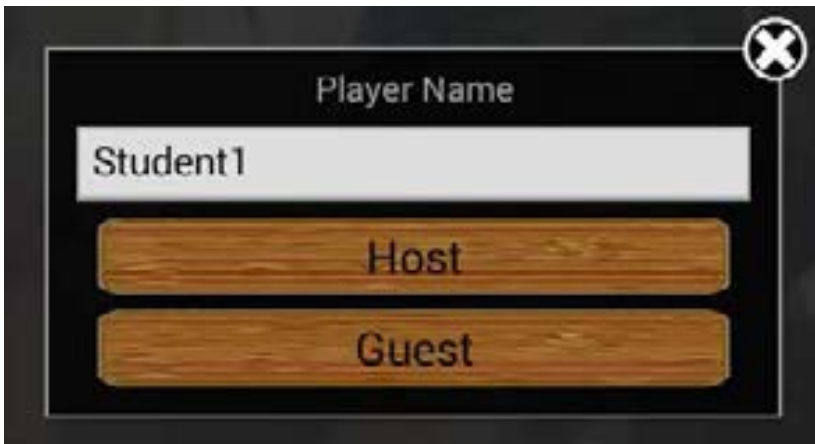


Figure 5.4. Bluetooth setup screen (adapted from **Paper VII**).





Figure 5.5. Game board showing two-player game session (adapted from **Paper VII**).

#### *Mapping Ayo game to programming skills*

A skill is the know-how and aptitude acquired through organized and attentive procedures over time. Possessing a skill supports the student to perform a particularly intricate assignment successfully. A learner's skills and enthusiasm differ significantly based on diverse situations [174], and the level of difficulty presented by a programming task demands proficiency in problem solving, pattern identification, and strategizing. However, learning to program offers the prospect of practicing important ICT skills such as problem solving and computational thinking. Therefore, the implementation of the Ayo game and Parson's programming puzzles was expected to aid the students with gaining programming skills while playing the indigenous game. The mapping of the Ayo game to conceptual modelling regarding computational thinking, problem solving, and basic programming skills is presented in Table 5.1. The Operation column in Table 5.1 is based on some topics given in [175].

Table 5.1. Conceptual modeling of Ayo game for computational thinking, problem solving, and basic programming skills (Adapted from **Paper VII**)

Operation	Mapped computational & programming skill set	Game activity
Input	Board with 12 small bins, 2 store bins, and 48 seeds	Two players arrange the seeds in bins
Output	Display game or data on the screen, save game data on the network	Play game on a network such as Bluetooth or Wi-Fi mode
Problem identification	How to capture all bins on the board? Winning tactic and scheming	Problem solving strategy: what moves are available at any given time? Is it a winning move?
Pattern identification and strategy	Game rules! The rule of the player sowing seeds when the last seed falls on the opponent's row, algorithmic problem solving, searching technique	Look-ahead depths, evaluation of opponent's moves, winning strategy formulation
Basic maths	Counting the seeds in the bin, performing basic mathematical operations like addition, subtraction, division and multiplication. For instance, the number of bins of a player after the first round of play is computed as total seeds captured divided by four.	Seed counting, emptying a bin when hollow with four seeds captured. Difference between the number of seeds in each player's store bin
Array and list concepts	Game board represents a 2 x 2 dimensional array. List structure for storing seeds and sequences of arbitrary length	Collecting seeds in a bin during game play
Conditions	Take decision on best moves. Game rules such as sowing, move, end round, and end game. Selecting playing mode,	Sowing rules represent programming conditions. Decisions are made at every step during game play
Loops	For example, Switch .... Case: To select player mode, player number	The entire game is a loop with certain rule-based steps until one of the players achieves the winning condition
Object oriented programming concepts	Bin – represents memory location for variables Seeds in a bin represent elements in an array Ayo game board represents programming objects with attributes Picking and placing seeds in a pit represent events	Players picking and dropping seeds into bins
Brainstorming and socializing	Analyze game situations at each point, develop winning strategies, anticipate results of actions	Check opponent's game style and strategies. Formulate your solution to win the game.
Debugging	Observe your solution to detect potential error in your losing strategy. Re-plan your logic.	When an opponent is capturing more bins than a player is, the player must debug his strategies.

*Integration of Parson's Programming puzzles into the Ayo board game*

The main idea is to teach basic programming concepts to novices using the Ayo game. Ayo game programming puzzles are a type of scaffolding program construction tasks where the learner is presented with a set of code fragments, blocks of single or multiple lines of code, and multiple-choice question types in the form of Parson's puzzles. The mission is to construct a working program from these skeleton codes, thus acquiring knowledge and comprehension of programming syntax, logic, and styles. Therefore, the goal is for the student to read and understand existing program codes, deduce logic, and decide how to solve the problem.

The Ayo game programming puzzle interface is constructed analogous to existing Parson's puzzle solutions [93, 165, 176, 177]. The scaffold codes are presented on the left side of the screen, and the right side is the solution. The players of the Ayo game are required to solve a programming puzzle at each round. On the problem area of the screen is a countdown timer, a player's name, the score, and a clickable label titled "Puzzle," which comprises the instructions for completing the task (Figure 5.6). Once a new task is shown, the *Puzzle* label becomes visible, which can be rendered either visible or invisible with a tap on the label. When the countdown time has elapsed, the player's puzzle session ends. A player is awarded 0.5 points for solving the puzzle correctly within the time period; otherwise, the player earns no points and loses the round.



Figure 5.6. Puzzle label is shown containing task instruction.

Afterwards, the Ayo game continues automatically. The right side of the screen, which is the solution area, is initially presented blank until the player drags and drops code snippets. The bottom part of the solution area comprises a *feedback* button and *five Stars*. When the player is satisfied with the answer provided for the puzzle, the player taps the *Feedback* button to obtain linear-type feedback. A star is awarded to a player who collects four points in a puzzle round. The idea of four points to a one-star gain is that the points can be used to acquire seeds in the Ayo game in future implementations. The Parson's puzzles offered to novices in the application concentrated mainly on a language-independent drag and drop of program codes, multiple-selection options, code indentation, and ordering. Figure 5.7 illustrates the drag and drop and indentation puzzles.

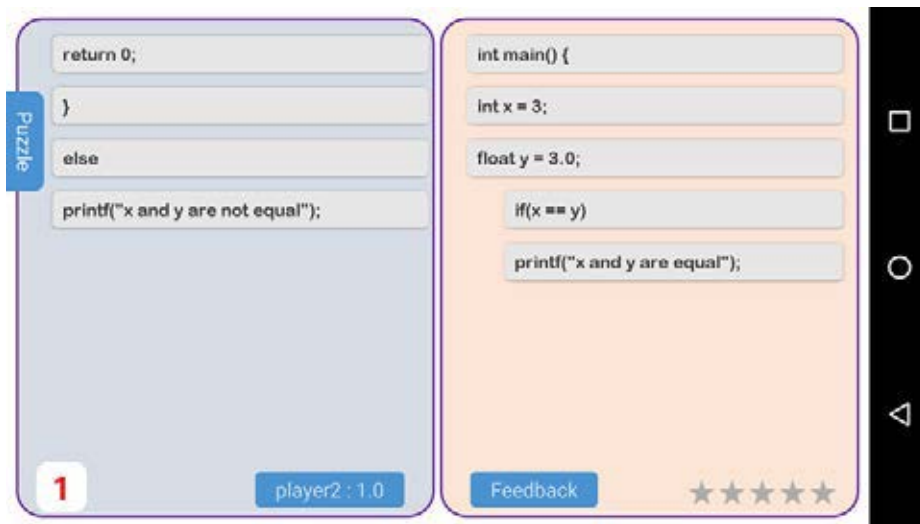


Figure 5.7. Drag and drop puzzle and indentation puzzle (adapted from **Paper VII**).

*Examples of basic programming tasks and solutions*

The followings are examples of programming tasks, steps to the solution, and the linear feedbacks, which are provided to the learners.

Example 1: The player’s task is to construct a program that calculates the factorial value of an integer. This example will guide the learner about the application of the “For loop” in the construction of a set of factorial numbers. Figures 5.8a, 5.8b, 5.8c, and 5.8d shows the steps taken by the player to complete the task.

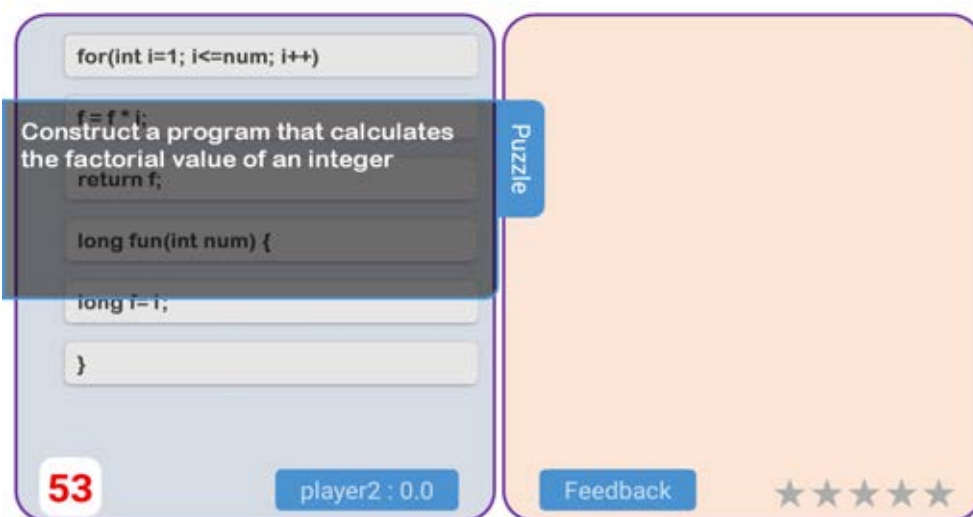


Figure 5.8a. Puzzle label indicating the description of the task.

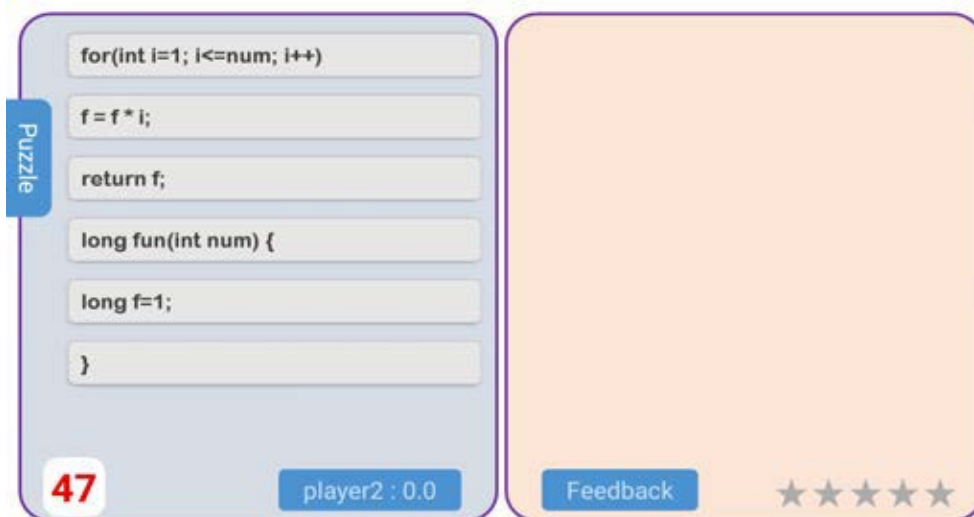


Figure 5.8b. An instance that the player has rendered the task description invisible and ready to solve the puzzle.

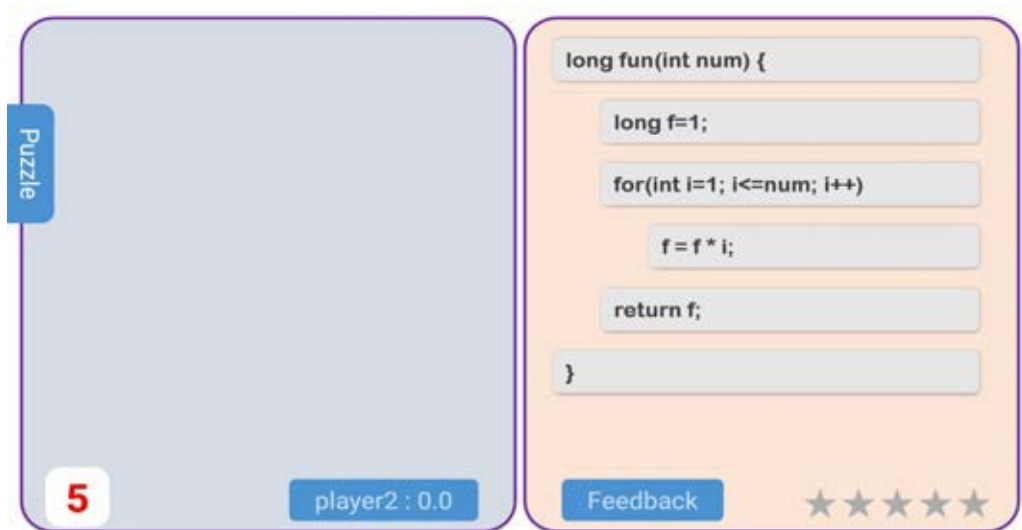


Figure 5.8c. An instance that the player has completed the task by code ordering, indentation, and drag and drop process.



Figure 5.8d. An instance that the player has tapped the feedback button and received a linear feedback.

Example 2: The player’s task is to construct a program that prints “Hello World! I’m a C++ program”. This example will aid the learner to practice the use of “cout” keyword in C++ to print a statement. The learner will also practice the C++ header,

body and the program composition. Figures 5.9a, 5.9b, and 5.9c shows the steps taken by the player to complete the task.

The screenshot shows a puzzle interface with two panels. The left panel is light blue and contains a code editor with the following code: `cout << "Hello World! ";`, `cout << "I'm a C++ program";`, `return 0;`, and `int main () {`. A dark grey overlay box contains the text: "Construct a program that prints Hello World! I'm a C++ program". A blue "Puzzle" label is on the right side of the left panel. At the bottom left of the left panel is a red circle with the number "51". At the bottom right of the left panel is a blue button labeled "player2 : 0.5". The right panel is light orange and is currently empty. At the bottom left of the right panel is a blue button labeled "Feedback". At the bottom right of the right panel are five grey stars.

Figure 5.9a. Puzzle label indicating the description of the task.

The screenshot shows the same puzzle interface as Figure 5.9a, but with the code blocks from the left panel now placed into the right panel. The code in the right panel is: `int main () {`, `cout << "Hello World! ";`, `cout << "I'm a C++ program";`, `return 0;`, and `}`. A blue "Puzzle" label is on the left side of the left panel. At the bottom left of the left panel is a red circle with the number "15". At the bottom right of the left panel is a blue button labeled "player2 : 0.5". At the bottom left of the right panel is a blue button labeled "Feedback". At the bottom right of the right panel are five grey stars.

Figure 5.9b. An instance that the player has completed the task by code ordering, indentation, and drag and drop process.



Figure 5.9c. An instance that the player has tapped the feedback button and received a linear feedback.

*Examples of data structures and algorithm tasks and solutions*

The Parson's concept is used in Ayo game on MobileEdu to formulate tasks for aiding the teaching and learning of algorithms. The followings are examples of algorithm tasks, steps to the solutions, and linear feedbacks, which are provided to the learners.

Example 3: The player's task is to order the time complexities from fastest to slowest. The time complexity is usually conveyed by means of the big O notation. For instance  $O(n)$ , where  $n$  is the input size. Figures 5.10a, and 5.10b shows the steps taken by the player to complete the task.





Figure 5.10a. Puzzle label indicating the description of the task.



Figure 5.10b. An instance that the player has completed the task by ordering the complexities from the fastest to the slowest, tapped the feedback button and received a linear feedback.

Example 4: The task of the player is to arrange the steps in implementing Kruskal's algorithm in solving the minimum spanning tree problem. Figures 5.11a, and 5.11b shows the steps taken by the player to complete the task.

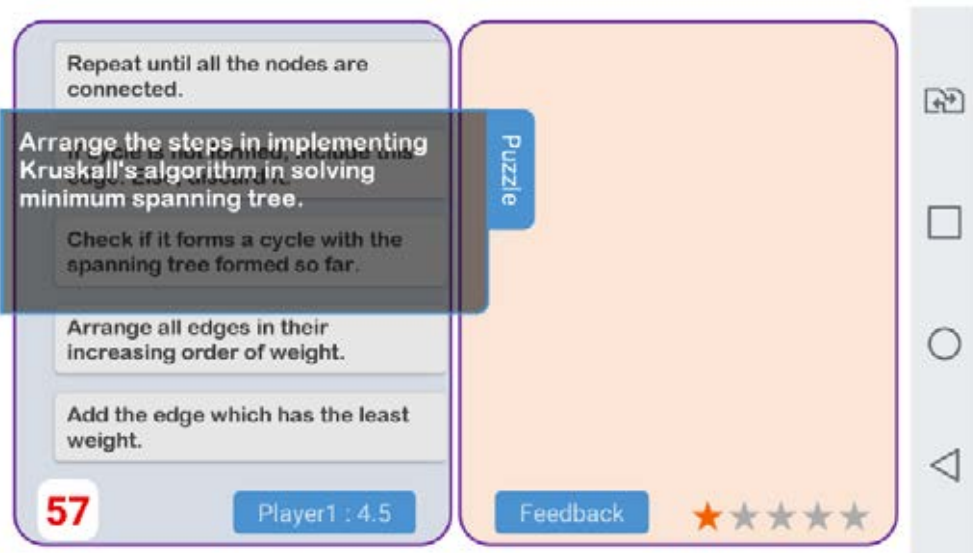


Figure 5.11a. Puzzle label indicating the description of the task.

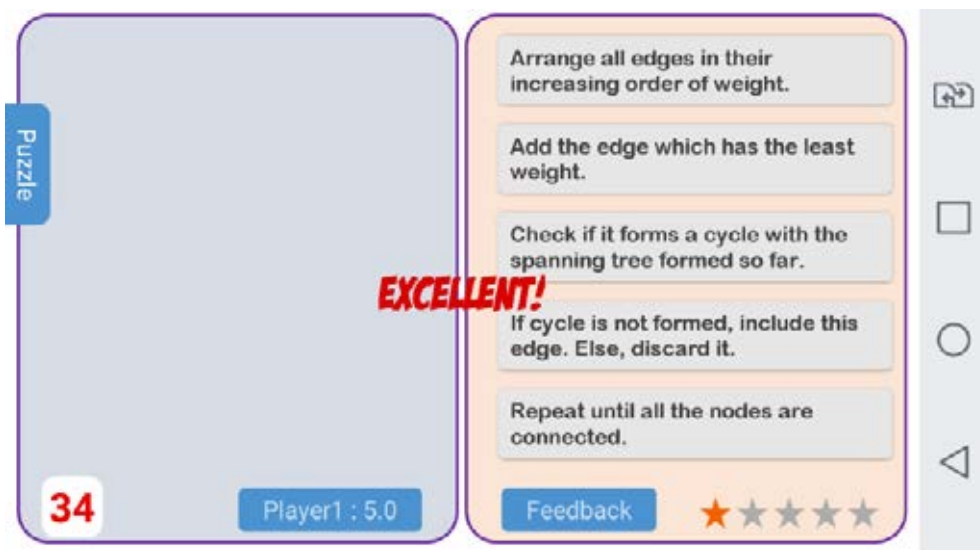


Figure 5.11b. An instance that the player has completed the task by ordering the steps in the implementation of Kruskal's minimum spanning tree algorithm, tapped the feedback button and received a linear feedback.

Example 5: The task of the player is to arrange the pseudocode that will implement the quicksort algorithm. Figures 5.12a, and 5.12b shows the steps taken by the player to complete the task.

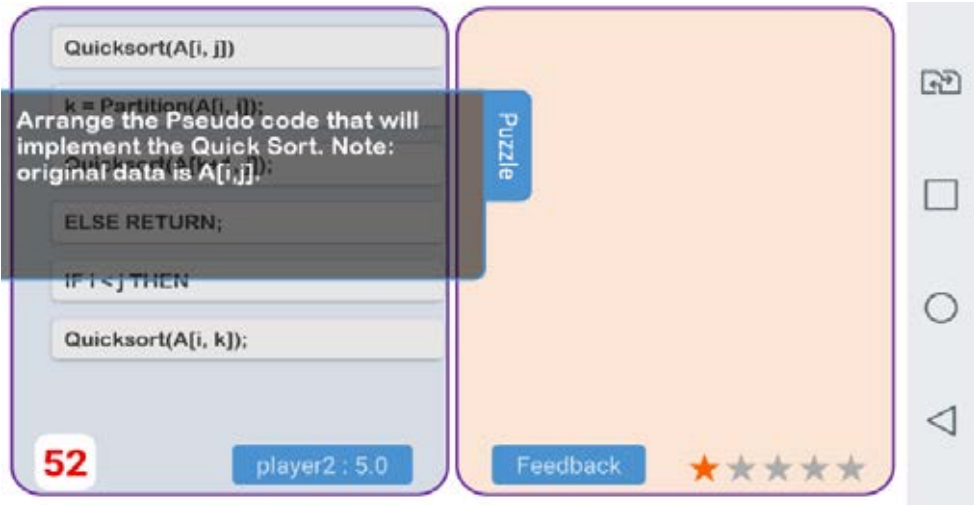


Figure 5.12a. Puzzle label indicating the description of the task.



Figure 5.12b. An instance that the player has completed the task by ordering the steps in the implementation of quick sort algorithm, tapped the feedback button and received a linear feedback.

### **5.3 SUMMARY**

The second DSR development cycle offered an expansion of the MobileEdu system. A traditional African strategy board game was implemented with Parson's programming puzzles on the system to further improve students' interactions, motivation, and engagement during computer science education. The chapter presented examples related to aiding learning of programming and algorithms concepts. Hence, the entire development cycle shows that developing mobile learning systems through a well-established pragmatic research technique, such as DSR, is beneficial, since it possesses specific procedures for problem identification, requirement definition, artifact development, evaluation, and iteration.

## 6 DISCUSSION

This research was dedicated to the design and development of a mobile learning system for computer science education in the Nigerian higher education context. The objective of the study was to seek better ways to use mobile devices as a learning tool in computing education and provide guidelines to successfully integrate mobile learning into mainstream education. To achieve this objective, a pragmatic research approach, DSR, was adopted for the research. DSR consists of five main components: explicating the problem; outlining the artifact and defining the requirements; designing and developing the artifact; demonstrating the artifact; and evaluating the artifact. The entire DSR process is iterative and incremental and, therefore, supports reflection by the researcher.

As illustrated in Section 2.3.1, behaviorists focus on reactions to stimuli, whereas cognitivists on inner mental processes. Furthermore, constructivist and connectivist theorists concentrate on the learner's interactions with the environment and the skills required in the digital era, respectively. In this study, learners of computing topics interacted with the learning environment, MobileEdu, in order to acquire concrete skills. In addition, since the aim was to seek better ways to support learners anywhere anytime, it was vital to select learning theories that underscore individual learning and collaborative learning in the digital era.

The unique characteristics of mobile learning have been summarized by the frameworks of several studies as presented in Table 2.1. Some of these features were considered while developing MobileEdu. For example, the characteristics of the adaptive learning framework proposed by Tan et al. [63], such as learner, location, time, learning content, and devices, play a role in my implementation. Similarly, the push and pull mechanisms, personalized content, collaborative content found in [5], and the educational gamification aspects of [74] are features available on the MobileEdu system.

In terms of the study's research questions, first, the study identified and investigated the practical challenges surrounding the limited interactions and lack of engagement among teachers and students in computer science education in Nigerian universities. I discussed these issues with my colleagues and some students in the department of computer science, Modibbo Adama University of Technology, Yola-Nigeria. A consensus was reached among the teachers and students to adopt the use of mobile devices to aid learning, and information was collected to assess the readiness to embark on mobile learning, in terms of the infrastructure required for mobile learning and ownership of mobile devices in developing country, Nigeria [**Papers I and VI**] [104]. The relevance of mobile devices in education is obvious; moreover, students already possess mobile devices to engage in learning, thereby reducing the imminent cost of implementing mobile learning [13, 178]. Further-

more, mobile technologies support learning experiences, which are interactive, engaging, collaborative, motivating, accessible, flexible, and integrated with the world outside the classroom. If properly expedited, mobile learning can benefit students by providing access to instructional materials and interactions through their mobile devices anywhere anytime. Similarly, teachers can interact with students and access pedagogical facilities flexibly [179]. However, the benefits offered by mobile learning do not come without challenges, especially in the context of a developing country. The main challenges of mobile learning in developing countries are categorized in **Paper I**, comprising technical, security, social, and pedagogical challenges. Moreover, Boyinbode et al. [180] offered a mobile learning system to support self-paced learning for students as a solution to the challenge of the lack of persistence of face-to-face lectures.

Second, the study identified the main pedagogical features of a mobile learning system to support learners and improve learning experiences. The mobile learning framework introduced in [66] highlighted three important features: authenticity, collaboration, and personalization. These features help educators and students to connect, communicate, collaborate, share, and access learning on the go. These functions are strategic for successful and meaningful learning to take place in any context. The study underscored that mobile learning in a learning context would not simply involve learning with mobile applications. However, it should provide innovative ways of learning and interacting in diverse contexts, both inside and outside the schoolroom. In particular, well-organized mobile learning systems and activities consider learners' needs and style, pedagogy, technology, context, social interactions, and collaboration. In fact, Barker et al. [181] presented coordination, communication, organization of material, motivation, mobility, interactivity, negotiation, and collaboration as critical success factors for mobile learning implementation. Moreover, **Paper III** identified the strategic relevance of social networking features of mobile learning and provided empirical data that social media enhances learning experiences. Furthermore, mobile technologies have a number of features that can be applied in computer science education [**Paper V**], such as mobile inputs, which serve as media that interact with the learner, outputs, which are outcomes from the learner's interactions with the mobile media, and the external resources, which connect mobile media and the learner's interactions.

Third, the study evaluated whether there is improvement in the learning achievement of students after using the mobile learning system. Furthermore, students' perspectives and attitudes towards the use of mobile devices in computer science education were evaluated. The purpose of any system is to achieve realistic performance after deployment. Therefore, since the mobile learning system was developed to support the learning goals of students, it was appropriate to measure the level of results obtained after using the system. In addition, the evaluation of the perceptions and attitudes of students using the mobile learning system for

computer science education indicated a positive view of the use of the tool among students. The results about improved learning achievement are consistent with previous studies [22, 157], which indicated that the use of mobile learning environments could enhance students' learning performance. Furthermore, the analysis of the results about the learners' perceptions and attitudes indicated that the use of a mobile learning tool in computer science education has an encouraging impact, which is consistent with outcomes of previous studies. This finding further confirmed the role of mobile learning in increasing the interest of learners and supporting collaboration and motivation [162, 182]. The applicability of the results will enable researchers and teachers to discern the needs of students regarding learning with mobile devices. Moreover, the results will help universities to understand and better support students in the achievement of their learning goals.

Based on experience from this study, the researcher identified the lack of persistent use of the mobile learning environment outside the school environment. This behavior could be associated with the lack of adequate experience among students on the use of technology-enhanced learning environments, and the inability of individual students to adopt the new technology. Therefore, providing student with institutional support, such as new technology awareness, will be relevant to improve the ubiquitous application of mobile learning and the discovery of potential advantages offered by new technologies [183]. Since several factors can influence learning achievement in any educational setting, it is often difficult to pinpoint the whole effect of the use of mobile technologies on learning. Consequently, the study endeavored to create a connection between the use of mobile devices for pedagogy and learning achievement by implementing a mobile learning system, and studying the users' attitudes, perceptions, and experiences.

## **6.1 GUIDING PRINCIPLES FOR INTEGRATING MOBILE LEARNING INTO COMPUTER SCIENCE EDUCATION**

This section itemizes the guiding principles for the implementation and integration of mobile learning into mainstream computer science education, especially in developing countries such as Nigeria. These principles are considered the theoretical or second outcome of the DSR approach, the first being the MobileEdu artifact. Furthermore, these guiding principles are based on the DSR process and the overall experience obtained from conducting this study. Moreover, these principles are dynamic, context-dependent, and could be improved further. Four aspects are important to consider during any educational technology integration effort: pedagogy, technology, context, and evaluation.

**Pedagogy aspect:** A focused and purposeful pedagogical strategy, embarked on by the teacher and supported by the institution and students, is one of the main pillars of successful mobile learning integration for computing education. Essential-

ly, the idea and model about mobile learning are similar to other types of learning. The design principles for effective knowledge acquisition on mobile devices are concretized through activities that support the subject of computing. Therefore, the design principles of mobile learning activities need to be guided by the pedagogical approaches of mobile learning for computer science education. A teacher can decide to combine some other suitable pedagogical approaches during a mobile learning activity. For instance, blended learning [161], collaborative learning [184], social learning [185], flipped learning [186], cooperative learning [187], inquiry-based learning [188, 189], game-based learning [190, 191], exploratory learning [192], online distance learning [193], active learning [142], and competition-based learning [194]. Similarly, teachers should consider the following when planning and designing the learning situation: the mobile technologies used; the learning content (computer science topic); the learning objectives; the interactions between the learner, devices, and learning content; how both the teacher and learner will use the mobile technologies to achieve the learning objectives; and how the learner could adapt to the use of the mobile device in different contexts. All these factors determine the learning achievement and experience of both teachers and students, and ultimately the overall learning goals. Furthermore, consideration should be given to the mobile device's usability, functionality, and development platform. It is important to conduct a survey to evaluate the mobile learning platform in order to select the most suitable for computing topics, since the mobile learning environment should be easy to learn, navigate, friendly, engaging, attractive, and intuitive to learners.

Technology aspect: A successful mobile learning-driven computer science education experience can be facilitated or undermined by the technology itself. Consequently, technology aspects are at the core of the successful integration of mobile learning in computing education. The guidelines entail that teachers would require professional ICT training to upgrade their skills in the use and application of technology-driven enhanced learning platforms, such as mobile learning. Huge technical challenges are envisaged in the use of mobile devices for learning, especially in computer science education, since the students are bound to use the mobile devices during the test-run of assignments, tasks, and coding. For example, the development and deployment of MobileEdu involved several technical requirements, such as Android system programming using JAVA, front-end development skills in JavaScript, and back-end development skills in databases and servers. Therefore, some basic computing skills are needed by teachers who want to apply mobile learning for computer science education. Similarly, based on my experience with the application of the MobileEdu environment in a real-life scenario, teachers should take some time to give practical guidance to the students about the new learning environment to avoid the "non-tech-savvy" disliking the lesson. More time is also required during the entire lesson to assist the students with technical difficulties arising from the use of the mobile devices. To avoid the network infrastruc-



ture and the mobile device's resources breaking down, the teacher should provide learning content in small chunks, and learning tasks should be linked to the lesson's content. Though it is important to focus more on lesson content and mobile learning than on the technology, it is essential to make the teaching and learning experience rewarding. The technology used should be compatible with a wide range of devices and media, accessible to all devices and everyone, protected with security and privacy features, and upgradable anytime anywhere.

**Contextual aspect:** Context is one of the most persistent characteristics of mobile learning since learning can take place anywhere, anytime. In both the formal and informal education contexts, mobile learning demands an adequate infrastructure and support for meaningful learning experiences. Consequently, educational establishments in Nigeria should outline their goals, missions, visions, and strategies for ensuring that mobile learning for computer science education is adequate and sustainable over an extended period of time. The approaches should cover matters connected to ICT integration, computer science curriculum upgrades, teachers' welfare and training, infrastructure upgrades, provision of conducive learning environments to support computing education, and security of all learning spaces. Integrating mobile learning into mainstream computing education could necessitate changes in technical support services, pedagogy, tools and technologies, administrative procedures, learning culture, and ultimately, human behavior towards the teaching and learning of computer science. Moreover, continuous deployments and upgrades of mobile technologies and ICT infrastructures will play a crucial role in the integration of mobile learning for computing education in Nigeria. For example, the provision of adequate infrastructures and teachers are core to curbing the dominant issues of large numbers of students in computing classrooms. Similarly, adopting pedagogical approaches, such as blended learning, flipped learning, social learning, and collaborative learning, would support teachers and lessen the issues created by overcrowded classes. Much attention should also be given to computer science teachers' professional development, as this will enable the teachers to obtain the necessary skills that are required for the implementation of mobile learning in the computer science curriculum.

**Evaluation aspect:** This aspect is focused on the outcome of the use of mobile devices in computer science-related activities. Considering the results obtained from the research, it is obvious that mobile learning has supported students to achieve better results in computer science topics. However, there should be continuous evaluations of the entire learning process, so that even better results can be achieved. Further evaluations should also be conducted to ascertain the level of outcomes that the mobile device-supported computer science learning has achieved in Nigerian educational settings, and how those outcomes can be further appraised for improved learning. Therefore, novel ways of evaluating mobile learning for computing education should be publicized. The findings in this research could be a

good reference for governments, parents, educators, and students. A national policy to support mobile learning in computer science education is hereby recommended for sustainable educational goals.

However, further work is required to develop an extensive and complete framework for the integration and application of knowledge about board games into mainstream computer science education on a global scale. I have already begun laying the necessary foundation for future work in this regard. The following are guiding principles designed for the integration of board games into computing education:

- identify the students' needs, particularly taking into account the local practices and contexts;
- create a brainstorming session to unravel the pedagogical attributes that are inherent in the indigenous artifacts, and map those to computing knowledge;
- craft a tool to mediate between learning content, conceptual understanding, and learning-by-doing; and
- invent a culturally responsive learning environment to support computer science education through board games, which is largely related to ethno-computing [195].

The guiding principles outlined above are an extension of the widely known Technological Pedagogical Content and Knowledge (TPACK) [196], which attempted to ascertain the landscape of relevant knowledge essential to teacher's efforts towards the integration of technology in teaching and learning, while acknowledging the intricate, multifaceted, and important nature of teacher knowledge. This dissertation, though focused on improving students' interactions and engagement in computer science, is relevant to improving teachers' output. The four-component guiding principles I recommend will ensure an effective technology integration for pedagogy around computer science education in different contexts, and guarantee sensitivity to the vibrant, transactional connection between these constituents of knowledge.

## **6.2 LIMITATIONS OF THE STUDY**

The research presented here describes the activities related to the development and evaluation of a mobile learning system for computer science education in the Nigerian context. The study accessed the readiness and suitability of mobile learning, identified key pedagogical features to implement mobile learning, and evaluated whether the mobile learning system can lead to improved learning achievement in a computer science education setting in Nigeria. Therefore, the results from this

study may not be generalizable to other curricula and contexts without further study.

The funding for the research was inadequate to cover the evaluation of the expanded version of the mobile learning system, and only one university was covered for experimenting with the tool, as funds were not available to conduct the experiment in many universities.

DSR, being an iterative and incremental approach, requires that the outcomes of the study are evaluated and improved. One limitation of this study is that its theoretical contribution is not evaluated.

New technology such as mobile learning integration in educational settings, whether formal, semi-formal, or informal, is not always perfect because teachers' and students' technology adoption capabilities differ greatly according to individual perceptions. For example, nowadays, we find more technology-savvy students adopting new technology faster than their peers and even their teachers. Hence, the concepts of active and passive integration of technology into education are broad. Generally, in the passive integration process, appropriate training is required for both teachers and students as part of their introduction to the technology before use. However, a tutorial for technology-savvy individuals may be directed towards advanced features, while less technology-savvy individuals would be given a basic tutorial. Therefore, technology integration is adaptive according to the needs and preferences of the individual. Similarly, the active integration process will possibly ensure that the learner obtains learning content in desired formats that are well-suited for the learners' prior knowledge. Unfortunately, in the context of this research, the technology was introduced without individual profiling and not enough time was given to the learners to become acquainted with the new technology.

An elaborate educational intervention, such as the one offered in this study, should obtain the teachers' and students' opinions before and after its implementation. The teachers' opinions in this study should have been evaluated, since they represent an important stakeholder in the use, integration, and successful pedagogical experience of the new tool. However, the teachers' opinions were sought during all the processes of developing the tool, but their opinions were not evaluated after the last implementation.

The low number of sampled universities may threaten the statistical generality of the experiment. At least, the experiment should have been replicated in few other universities across Nigeria to ensure that the results are widely generalizable. Moreover, further experiments should have been conducted to evaluate the latest version of the system after the introduction of games and programming features. Additionally, there is already an inherent limitation, which could be associated with the game and the programming mobile learning environment. The main limitation of the new tool is that playing an indigenous African game might not be significant or interesting to learners across other contexts. Furthermore, I cannot assert

that the game would offer fun and engagement to all learners, nor can I assume with conviction the effect of puzzles and games with additional variables, for instance, learning achievement, emotional feeling, level of success, collaboration, interest, and social interaction.

## 7 CONCLUSION

In this dissertation, we have developed a mobile learning system to support teaching and learning of computer science courses in the Nigerian university context. The study stimulates the use of mobile devices as a learning tool and provides relevant guidelines for integrating mobile learning into the educational system. The research was conducted according to DSR, and reflections on the application of mobile learning to students' learning achievement were discussed. Four research questions were formulated from the research problem. Consequently, the work provided answers to these research questions as follows.

### 7.1 ANSWERS TO THE RESEARCH QUESTIONS

**Research question 1:** *What is the level of readiness and suitability of mobile learning to support computer science education in the context of Nigerian higher education institutions?*

This question was answered by conducting a survey, analyzing the literature, and deriving conclusions based on several years of teaching in the research context, Nigeria. The field survey was used to collect information about the readiness of Nigeria to integrate mobile learning into mainstream education. Similarly, the survey contained items that examined the suitability of using mobile devices for computer science education, whether the country has the necessary infrastructure, such as mobile communications, and whether the students own the required mobile devices and are willing to use the devices for learning. Furthermore, to answer this question, the challenges facing mobile learning adoption and whether the country can overcome these challenges were examined. The results from these studies were presented in **Paper I** and **Paper II**. The results indicated that Nigeria possesses the required mobile telecommunication infrastructure, but electricity and other infrastructures are erratic. Similarly, the ownership of mobile devices by many students, their willingness to learn on mobile devices, and their familiarity with several features of the devices are encouraging prospects pointing to students' readiness for the learning opportunities created.

**Research question 2:** *What are the key pedagogical features to implement in a mobile learning system to support learners and improve learning experiences in the context of Nigerian higher education institutions?*

Several pedagogical features are required for successful teaching and learning in the 21st century. Some of these features were examined and the opinions of learners

were surveyed through interviews and questionnaires in **Paper III** and **Paper V**. Notably, the learners were keen to have social networking features, communication, educational games, and collaborative features on the learning environment. The results also show that mobile learning for computer science education has the potential to increase learner's affective traits, and the Android mobile operating system was a popular solution for use in mobile learning. Several input and output features on mobile devices relevant to computer science education were identified in **Paper V**. Similarly, the results revealed main aspects of mobile learning, such as mobile development platforms, pedagogical approaches, subject areas of computer science education, technological features, learning effects, and learner context.

**Research question 3:** *Is there an improvement in students' learning achievements and attitudes after using a mobile learning system for computer science education in the context of Nigerian higher education institutions?*

To answer this question, a mobile learning environment, MobileEdu, which comprised the pedagogical features identified in **research question 2**, was developed and evaluated. The evaluation was conducted in a Nigerian university with 142 third-year undergraduate computer science students, which investigated the level of achievement after using the mobile learning environment. A mixed method research approach was applied to examine the impact of using MobileEdu on the pedagogical outcomes of the learners and to unravel learners' perceptions about the learning environment. The results of the development and evaluation are presented in **Paper VI** and **Paper VII**. The results of the investigation revealed that the use of MobileEdu supported the learners to achieve better learning results and pedagogical experiences.

**Research question 4:** *What kinds of guiding principles can be given to stakeholders in the context of Nigerian higher education institutions about mobile learning implementation and integration in computer science education?*

The guiding principles for integrating mobile learning into mainstream computing education follow four aspects: pedagogy, technology, context, and evaluation. The guidelines regarding pedagogy during the process of implementing mobile learning entails a combination of several learning approaches to foster a robust learning environment, as enumerated in Section 5.1. These learning paradigms not only provide theoretical backings to mobile learning, but they also ensure that learning goals are achieved. The success of any technological intervention, such as mobile learning, demands that users receive constant training and practical guidance, especially the teachers and students who are the main actors in mobile learning. Contextual factors are considered relevant in the implementation effort of mo-

mobile learning, since these factors can complicate the relationship between learning and technology. Adequate infrastructures and equipment, a strategic instructional plan, and a suitable transfer of knowledge are important factors to safeguard contextual pitfalls during mobile learning integration. Finally, the guiding principles also support the constant evaluation of mobile learning integration as a feedback mechanism, and ensure the timely improvement of the whole process. If carefully followed, these recommendations will ease the challenges faced in the adoption and use of mobile devices in the education sector.

## **7.2 FUTURE RESEARCH**

This study has shown that it is possible to build a mobile learning system that is capable of supporting several pedagogical features in computer science education. In addition, several further questions and new research directions that could be pursued in the future are presented.

The first aspect of future research could focus on evaluating the system in several contexts, because thus far, the system was built in the Nigerian context. In so doing, the results presented in this study could be compared with the results from another context to validate the study and open the possibility of the emergence of a fresh concept, pedagogy, and methodology.

The theoretical contribution presented in Section 6.1 should be evaluated to verify whether it is relevant for the intended purpose. Moreover, since these guiding principles are based on the DSR process and the experience obtained from conducting this study, there is a need for evaluation. These guidelines could change according to factors such as time and context. The evaluation could involve setting a new cycle of the DSR approach, especially in the Nigerian context with several educational stakeholders, such as students, teachers, school administrators, parents, and the government.

A subject-specific solution should be encouraged in computer science education. In particular, the objectives and outcomes of mobile learning in computer science education should be examined systematically and profoundly. Hence, longitudinal research about the use of mobile devices in computer science education is needed.

Further studies are needed to develop a model to explicate the relationships between mobile learning in computer science education and affective traits, such as teamwork, collaboration, engagement, motivation, excitement, confidence, critical thinking, and enthusiasm. The model can reveal an unknown view of mobile learning in computer science education, and possibly strengthen the field by engaging teachers to understand the students more deeply and promote learner-centered pedagogy.

The mobile learning environment developed in this research constitutes a proof-of-concept system that promotes the use of mobile devices to support learning in

computer science. Future work could improve the system. Possible improvements in the system include: learner profiling and learning styling for the purpose of creating a smart learning environment that provides learning content according to the student's learning style and needs; development for other mobile operating systems, such as iOS and Windows RT; further investigation about the programming interface to ascertain its usability and assess whether the tool rendered the intended support to improve novices' programming skills; and moreover, there is need for an experiment to establish the impact of the programming interface on split-attention and cognitive load during the process of solving programming tasks.

This study has paved the way for another developmental concept because the proposed solution of integrating Parson's puzzles with a strategy board game offers a new perspective on how to use mobile devices when learning to program. A future step in this direction is to develop a framework for integrating board games into computer science education. The framework would support indigenous board games from different contexts.



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# APPENDICES

## APPENDIX 1.

### Questionnaire 1

Dear respondent,

University of Eastern Finland researchers have been developing a mobile learning platform for learning ICT/programming. We have prepared this questionnaire in order to find out the impact of using your mobile devices for Computer studies. We would greatly appreciate if you would respond to the questions sincerely and honestly. Your responses and information will be kept strictly confidential. Thank you very much for your cooperation.

### DEMOGRAPHIC DATA:

**Please tick (✓) in appropriate box**

School Name:

.....

Gender:

Female

Male

Age:

16 – 20 years

21 - 25 years

26 – 30 years

31 – 35 years

36 years and above

### PART A – MOBILE DEVICE OWNERSHIP

**NOTE:** For the purpose of this research work, mobile device includes any of the following; Mobile Phone, Smart Phone, Tablet, PDA, Pocket PC, e-Reader, and MP3 Player.

#### 1. Identify your kind of mobile device(s):

Mobile Phone

Smartphone

Tablet  PDA

Pocket PC

e-Reader

MP3 Player

Other mobile device (please specify)

.....

**PART B: DEVICE FEATURES & FREQUENCY OF USE**

**2. Estimate how much you use the following functions of your device:**

<b>Device Features &amp; Frequency of Use</b>	<b>Several times a day</b>	<b>Once a day or less</b>	<b>Once a week</b>	<b>Once a month</b>	<b>Never</b>
Send /receive emails	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Social media & Chatting (e.g. Facebook, WhatsApp, Twitter)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Making Calls & Texting (SMS)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Taking photos & videos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Play educational games	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Browsing internet (e.g. Google)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Read e-books/pdf	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Listen to recorded session	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Complete homework & assignments	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Practice online quizzes/exams	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**3. Do you use your mobile device when you are at this place(s)?**

Select all that apply

College/University  Home  Work  In Transit

Playground/Park

Other places (please specify)

.....



## PART C: IMPACT OF MOBILE DEVICE FOR LEARNING

### 4. Identify impact of using mobile device for learning:

Learning Impacts	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
I found it useful that I can learn on a mobile device anywhere anytime	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
learning apps on the mobile device were easy to use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I prefer using mobile device such as smartphone as opposed to a textbook for learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The learning activities on the mobile device helped to improve my skills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I found it relevant to use mobile device for my home works & assignments	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## PART D: INFLUENCE ON MOTIVATION AND INTEREST

### 5. Identify influence on motivation and interest:

Influence on motivation & interest	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
Mobile device features inspire my learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mobile learning motivates me to learn more wherever I am	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It is interesting to learn through mobile device	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I found it motivating to use mobile device for home works and assignments	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**PART E: LEARNERS' EXPERIENCES WITH M-LEARNING**

**6. Identify your experiences with mobile learning:**

<b>Learners' experiences with mobile learning</b>	<b>Strongly disagree</b>	<b>Disagree</b>	<b>Unsure</b>	<b>Agree</b>	<b>Strongly agree</b>
I found learning more engaging with mobile device	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It is more convenient to learn with mobile device	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mobile learning provide learners more flexibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The features of mobile device support more interactivity with learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**PART F: FACTORS INFLUENCING MOBILE LEARNING ADOPTION**

**7. In your opinion, what are the factors affecting the adoption of mobile learning in your institution?**

Select all that apply

- Mobility
- Insecurity
- Poor infrastructural development
- Ownership
- Affordability
- Acceptability
- Technical challenges such as different screen size, products etc.
- Added complexity
- Low computer literacy
- Poor learning environment

## APPENDIX 2.

Questionnaire 2 (Pre-module questionnaire)

Dear Participant,

My name is Solomon Sunday Oyelere, I am Doctoral researcher at (IMPDET) under the supervision of Prof. Erkki Sutinen and Dr. Jarkko Suhonen. My research topic and interest is development of mobile learning platform to learn ICT/Programming at university level. Currently I am researching the use of social media technology in mobile learning: case study of Edmodo in learning computer science in developing country scenario and for this reason I would appreciate your participation in this survey. Moreover, the results of the research may be published, but your name will not be used. Any data collected as part of this study will be used only with other educators for research or educational purposes. If you have any questions concerning the research study, please call me on my skype account solomon.oyelere or you may also reach me by e-mail at solomon.oyelere@mautech.edu.ng. If you prefer, you may also contact Dr. Jarkko Suhonen in person.

Thank you in advance.

Sincerely,  
Solomon Sunday Oyelere

I have read the information given above. I hereby consent to participate in the study:

Yes  No

### PART A: DEMOGRAPHIC DATA

Please tick (✓) in appropriate box

Name:

.....

Gender:

Female

Male

Age:

16 – 20 years

21 - 25 years

26 – 30 years

31 – 35 years

36 years and above

Level of studies:

100 level

200 level

300 level

400level

500level

Main study subject:

.....

**PART B: FAMILIARITY, FREQUENCY, AND CONTEXT OF USE OF SOCIAL MEDIA TOOLS**

**1. What does the term social media tool mean to you?**

.....

.....

.....

.....

.....

**2. What do you consider to be the benefits of social tools for learning?**

.....

.....

.....

.....

.....

**3. Estimate how familiar you are with the following social media tools:**

<b>Familiarity with social media as users</b>	<b>Very familiar</b>	<b>Familiar</b>	<b>Somewhat familiar</b>	<b>Not so familiar</b>	<b>Not known</b>
Blog	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wiki	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Social network	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mobile learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Video podcast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Audio podcast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Chat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Social bookmarking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Virtual worlds	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Media sharing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**4. How frequent do you use social media tools?**

Frequency of use of social media tools	Daily	Weekly	Monthly	Occasionally	Never
Blog	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wiki	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Social network	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mobile learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Video podcast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Audio podcast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Chat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Social bookmarking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Virtual worlds	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Media sharing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**5. In what context do you use social media tools?**

Context of use of social media tools	Personal	Part of learning course work	Recreational use	Not used	Other(s)
Blog	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wiki	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Social network	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mobile learning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Video podcast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Audio podcast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Chat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Social bookmarking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Virtual worlds	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Media sharing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Other(s) context, please specify**

.....

.....  
.....  
.....  
.....

**6. Have you used any social media tool(s) as a learning aid?**

Yes  No

If Yes answer Q7 and Q8 but if No then answer Q9.

**7. What would you prefer to use in learning?**

**Preference for learning**

- Blog
- Wiki
- Social network
- M-learning
- Video podcast
- Audio podcast
- Chat
- Social bookmarking
- Virtual worlds
- Media sharing

**8. Why do you prefer to use the indicated tool(s)?**

.....  
.....  
.....  
.....

**9. Do you believe that social media can possibly improve your learning process?**

Yes  No

If Yes, why?

.....  
.....  
.....

.....  
**If No, why not?**

.....  
.....  
.....  
.....  
.....

**PART C – MOBILE DEVICE USAGE FOR SOCIAL MEDIA**

**NOTE:** For the purpose of this research work, mobile device includes any of the following; Mobile Phone, Smart Phone, Tablet, PDA, Pocket PC, e-Reader, and MP3 Player.

**10. What kind of device(s) you currently use/have used previously for accessing social media?**

Desktop PC  Laptop  Mobile device

Other device (please specify)

.....

**11. Why do you prefer to use the indicated device(s)?**

.....  
.....  
.....  
.....  
.....





### APPENDIX 3.

#### Questionnaire 3 (Post-module questionnaire)

Dear Participant,

My name is Solomon Sunday Oyelere, I am Doctoral researcher at (IMPDET) under the supervision of Prof. Erkki Sutinen and Dr. Jarkko Suhonen. My research topic and interest is development of mobile learning platform to learn ICT/Programming at university level. Currently I am researching the use of social media technology in m-learning: case study of Edmodo in learning computer science in developing country scenario and for this reason I would appreciate your participation in this survey. Moreover the results of the research may be published, but your name will not be used. Any data collected as part of this study will be used only with other educators for research or educational purposes. If you have any questions concerning the research study, please call me on my skype account solomon.oyelere or you may also reach me by e-mail at solomon.oyelere@mautech.edu.ng. If you prefer, you may also contact Dr. Jarkko Suhonen in person. Special thanks to my colleague Vasileios Paliktoglou for supporting us with relevant information and questionnaire contents.

Thank you in advance.

Sincerely,

Solomon Sunday Oyelere

I have read the information given above. I hereby consent to participate in the study:

Yes  No

#### PART A: DEMOGRAPHIC DATA

Please tick (✓) in appropriate box

Name:

.....

Gender:

Female

Male

Age:

16 – 20 years

21 - 25 years

26 – 30 years

31 – 35 years

36 years and above

Level of studies:

100 level

200 level

300 level

400level

500level

Main study subject:

.....

**PART B: IMPACT OF EDMODO**

**2. Estimate how much you use the following functions of your device:**

<b>Items</b>	<b>Compl- etely disagree</b>	<b>Disagree</b>	<b>Neither agree nor disagree</b>	<b>Agree</b>	<b>Completely agree</b>
Did the course and use of the Edmodo (tool) environment meet your expectations?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Edmodo environment facilitated my participation in the course	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Edmodo environment supported me to get to know others in the course and/or create a sense of comfort and community	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Edmodo environment supported me to work with others in the course, building on ideas or resources together?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Edmodo environment supported me to discuss course concepts with others in the course	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Edmodo	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

environment supported  
me to get more  
information or support  
from the instructor

Do you believe that       
the instructor's  
participation influenced  
your usage of the tool(s)?

Do you believe that       
the use of the Edmodo  
environment adds value  
to your overall learning  
experience in the course?

The Edmodo       
environment supported  
me to connect concepts  
with cases and examples

The Edmodo       
environment facilitated  
personal reflection

The Edmodo       
environment supported  
me to capture my thoughts  
on what I was learning

Do you think the use       
of the Edmodo environment  
added to the intellectual  
value of the course?

Do you think the       
course structure of the  
assignments influenced  
your usage of the tool(s)?

Would you suggest       
the use of this approach

(use of the Edmodo environment) in other courses?

**PART C: IMPACT OF EDMODO (FREQUENCY)**

Items	No Answer	Never	Occasionally	Weekly	Daily
At what frequency did you produce content with the introduced social media tool(s)?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At what frequency did you read the content produced by other students in the course?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**PART D: IMPACT OF EDMODO (MOTIVATION)**

What motivated you using the introduced Edmodo (tool) environment?

- Course structure
- Interest in the subject
- Group work
- No answer
- Other

**PART E: EDMODO IN MOBILE LEARNING**

18. What kind of device(s) you use for accessing Edmodo?

Desktop PC  Laptop  Mobile device

Other device (please specify)

.....

19. Why do you prefer to use the indicated device(s) for accessing Edmodo?

.....

.....

.....

.....

.....

20. Do you have aspiration to learn on mobile device anywhere anytime (m-learning)? Yes  No

21. Does Edmodo support your aspiration to learn on mobile device anywhere any-time (m-learning)?

Yes  No

22. Do you have other comments or suggestions to help improve the use of the in-troduced Edmodo (tool) environment in courses?

.....  
.....  
.....  
.....  
.....



## **APPENDIX 4.**

### Interview questions

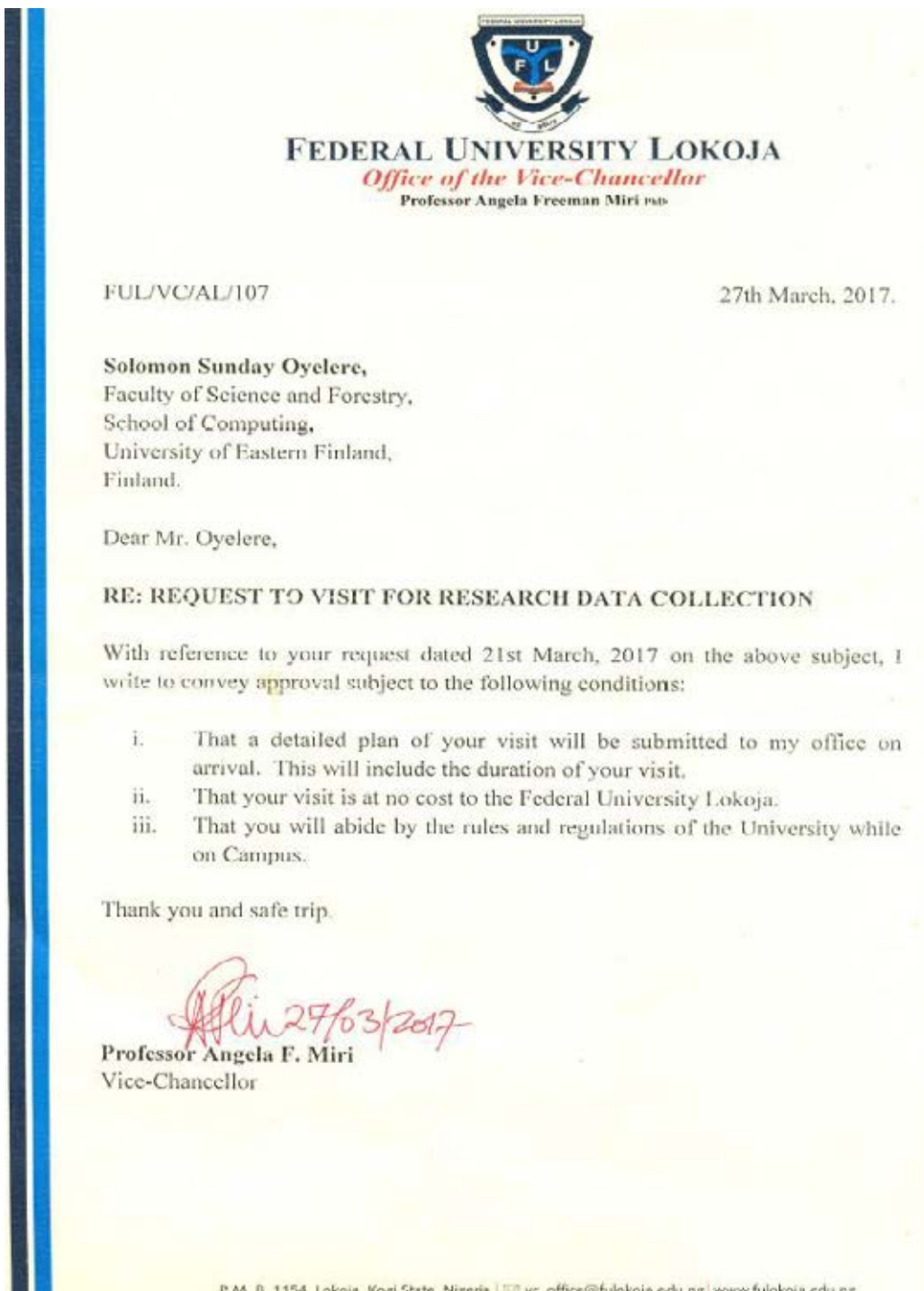
1. Does Edmodo meet your expectation of a social media tool?
2. What features did you like in Edmodo?
3. What was working well? What needs to be improved? Can you please list three good aspects (or features/ functionalities) of Edmodo and three aspects (or features/functionality) that needs improvement.
4. How would you compare Edmodo to other social media tools for learning such as facebook?
5. Please describe any problems that you may have faced using Edmodo.
6. What features you think should be added to Edmodo? Explain the benefits or added value of such features.
7. What is your perception of the use Edmodo for educational uses?
8. Do you think that students/ teachers could benefit of using Edmodo? Explain how.
9. Does Edmodo motivate your learning?
10. What is your experience of using mobile device to access social media tool such as Edmodo? State both positive and negative experiences.
11. Does learning on mobile device motivate you to learn more? Why?
12. Do you have other comments or suggestions to help improve the use of Edmodo in m-learning?





## APPENDIX 5.

An invitation letter to conduct research experiment at a Nigerian university.



## SOLOMON SUNDAY OYELERE

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*The ubiquitous and pervasiveness of mobile devices is changing how people learn, work, communicate, interact, and share experiences. This book seeks better ways to use mobile devices as learning tools in computing education within infrastructure-constrained environments. A mobile learning application, MobileEdu, was developed and evaluated, capable of supporting learners in a game-based programming educational setting. Furthermore, this book offered strategies to effectively incorporate mobile learning into mainstream education.*



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