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Cloud-based m-learning: A pedagogical tool to manage infrastructural limitations and enhance learning

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ABSTRACT

The concept of blending mobile learning and cloud computing (cloud-based m-learning) is potentially a strong fit for higher education in developing countries with inadequate infrastructure. Notwithstanding the potential benefits, while a substantial number of theoretical studies exist, there are limited studies focusing on the practical implementation of such learning opportunities. Leveraging on the success of mobile technology in Nigeria, this study proposes a contextual cloud-based m-learning model. To explore the suitability of the proposed model in practice, a case study based trial was conducted using a blended approach, in which m-learning complemented the traditional teaching and learning in a Nigerian university. Applying the principles of social constructivism and the theory of optimal experience (Flow), learning was designed to be collaborative, motivating and engaging. Data were collected via questionnaire and observation of 208 undergraduate students. The outcome of the trial showed that cloud-based m-learning offered practical solutions to the limited IT infrastructure at the university and allowed for the merits of student-centered learning to be gradually introduced. This had a positive self-reported impact on students' learning. This study demonstrates how cloud-based m-learning exploiting local opportunities, can be effectively implemented to enhance learning in higher institutions with a paucity of resources.

Keywords*:* *Cloud computing; mobile learning; blended learning; social constructivism; Flow; WhatsApp; Cloud-based m-learning; model*

INTRODUCTION

The use of technology to facilitate teaching and learning in higher education has risen in popularity over the last decade. It is therefore "no longer considered a novelty or the domain of enthusiasts alone" in developed countries, and developing countries are leapfrogging from unwired, non-existent infrastructure to wireless infrastructure due to advancements in mobile technology (Kirkwood & Price 2014, p:3). The deep penetration of the mobile technology and affordability of mobile devices provides the enabling environment for m-learning (Mtebe & Raisamo 2014); such that it has been argued, m-learning could bridge the digital divide in educational technologies between advanced and emerging societies (Curry, Dumu & Koczberski, 2016). Accordingly, one would expect a high implementation rate of m-learning in higher education in developing countries. However, this has not been the case (Lamptey & Boateng 2017; Okai-Ugbaje, Ardzejewska & Imran, 2017). The low adoption rate has been attributed to limitations such as short battery life, limited memory and processing power of mobile devices, infrastructural barriers and the cost implications of providing quality IT services (Asabere 2013; Okai-Ugbaje, Ardzejewska & Imran, 2017). It is envisaged however, that such challenges can be managed using cloud computing (Baalghusun & Qureshi 2014; Rimale et al. 2016).

Cloud computing has emerged as a viable and promising solution not only for emerging societies with limited funding and IT infrastructure, but also for developed countries where there are cuts in institutional IT budgets in the face of increasing demands for IT services (Pardeshi 2014). It is defined as

> *"a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell & Grance 2011, p. 2).*

The cloud technology is composed of five essential characteristics (on-demand self-service, broad network access, resource pooling, rapid elasticity and measured services), three service models (Software as a Service, Platform as a Service and Infrastructure as a Service) and four deployment models (private, community, public and hybrid clouds) (Mell & Grance 2011).

M-learning using cloud computing (cloud-based m-learning) is an emerging area with researchers such as Badidi (2016), Hirsch and Ng (2016), arguing that it holds tremendous promise for educational development. This new paradigm combines the benefits of cloud computing and m-learning, where data processing, power and storage "happens outside of the mobile device" (Masud & Huang 2013, p. 84). It is likened to a public utility where consumers (educators and learners) can plug in anytime, anywhere (Teall, Wang & Callaghan, 2014). This eliminates the need for complex and expensive IT infrastructure and extends learning opportunities not only to sophisticated smartphones, but also to low range devices, provided they have a web browser (Badidi 2016; Masud & Huang 2013). Consequently, it helps to overcome obstacles related to mobile devices and traditional m-learning, and provides the avenue to potentially deliver a seamless m-learning experience to a larger audience.

Two integral aspects of m-learning are the technological and pedagogical dimensions. The technological dimension relates to how learning is delivered through mobile devices, which may or may not be cloud-based, while the pedagogical dimension ensures that learning using mobile devices is both effective and meaningful. Cochrane (2014) argues that both dimensions should be given equal attention and made to complement each other for best outcomes and productive m-learning to occur. To explore the synergy between the technological and pedagogical aspects of m-learning, this study set out to investigate:

(1) how a cloud-based platform used to complement the traditional face-to-face teaching and learning in a Nigerian university might alleviate the technological and infrastructural challenges; and
(2) the potential impact on the learning experience of students.

Nigeria, like many developing countries is faced with infrastructural challenges that have hindered the provision of quality IT services to facilitate teaching and learning with technology. Sitting alongside this is the traditional classroom approach with limited use of technology (Eze, Chinedu-eze & Bello, 2018; Olutola & Olatoye 2015). Given the widespread integration of mobile technology in the country and ownership of mobile devices by the majority of higher education students (Liadi 2016; Mojaye 2015; Utulu & Alonge 2012), m-learning offers the possibility to reimagine the delivery of higher education. This paper builds on the findings of an earlier investigation, an exploratory study conducted at the same university, to determine stakeholders' attitude to and readiness for m-learning. The findings of that study showed that students were keen to engage in m-learning (Okai-

Ugbaje, Ardzejewska & Imran, 2020). This article therefore explores whether students' overwhelming positive attitude to m-learning in theory translates into practice.

LITERATURE REVIEW

Cloud-based M-learning

Cloud-based m-learning offers learners the opportunity to access text-based, audio and video content without having to worry about the storage capacity or computational capabilities of their mobile devices (Wang, Chen & Khan, 2014). It also provides free or low-cost alternatives to make content available to students (Parakkal, Singh & Mahadevan, 2016). Notwithstanding the potential benefits, a review of the literature found that, while a substantial number of theoretical studies exist, there are limited practical implementation studies from developing countries. Such implementation studies include those of Wang, Chen and Khan (2014) who explored the potential of m-learning in the cloud in universities of less developed countries of the Middle East. In the study, Moodle (a learning management system) was customized to run on Microsoft's public cloud platform (Azure), which students accessed using any mobile device not only while they were on campus, but also off campus provided they had access to the Internet. The authors reported that improved access to resources helped to facilitate a more collaborative learning environment. In a related study, Heng and Zhong (2016) explored the implementation of cloud-based m-learning in China using the Platform as a Service (PaaS) delivery model. The goal was to offer a cost effective and cross-platform m-learning solution to address collaboration and content delivery problems. It was reported that cloud computing offered a scalable solution to m-learning. In addition to easy access to the content and improved collaboration, students reported that watching the cloud-hosted video tutorials with their mobile devices before class improved their understanding and made learning more interesting.

The review also found studies from India that proposed cloud-based m-learning architecture for effective m-learning and collaboration between students and educators (Dhanalakshmi, Suganya & Kokilavani, 2014; Paliwal, Pushpalatha & Boraiah, 2016). Similarly, studies from Africa have also recognized the potential of cloud computing to effectively aid m-learning and expand access to educational opportunities in the region, despite limited resources and infrastructural challenges (Asabere 2013; Boyinbode & Akintade 2015; Mouyabi 2012; Oyelere, Suhonen & Sutinen, 2016). Missing from these investigations is an empirical study from the perspective of African countries such as Nigeria, focusing on innovative, locally suited solutions demonstrating the effectiveness of cloud-based m-learning in practice.

Pedagogical Considerations for M-learning

As seen from previous studies outlined above, only collaboration and communication in learning have been considered. While these are important pedagogical practices, m-learning requires greater attention given the intrinsic and ubiquitous nature, ownership and control of mobile devices that can make learning with them motivating and enjoyable (Laurillard 2007). Therefore, it is important that the design of m-learning is underpinned by theories that not only foster collaboration, but also ensure engagement and enjoyment of learning, while offering appropriate challenges to ensure learning is meaningful. Two learning theories that support this argument are the social constructivist theory and the theory of optimal experience (Flow). Additionally, both theories are a strong influence in 21^{st} century higher education which requires student-centered learning (Power 2013).

According to the principles of the social constructivist theory, learning is a social activity, and meaningful learning occurs through active engagement (Flint 2016; Hanson & Sinclair 2008; Thomas et al. 2014). The learning environment should be democratic, to allow for crucial interaction amongst students and with educators (Secore 2017; Amineh & Asl 2015). These principles help students to relate with what they learn; and by working in groups, reflect on their understanding, refine their knowledge and have a shared understanding of the content (Baharom, 2013). This likely explains why Cochrane and Bateman (2010) described social constructivism as the overarching strategy and preferred pedagogy underpinning higher education teaching and learning. Furthermore, given contemporary students' predilection for using mobile devices for numerous activities, including for fun, learning with mobile devices should be designed to compete with these interests while providing meaningful learning that can maintain students' attention, as well as improve their concentration and interest in the m-learning material (Li & Yang 2016). Flow potentially offers such outcomes.

Csikszentmihalyi (1975) defines Flow as the "the holistic sensation that people feel when they act with total involvement" (P.36). The author argues further that, autotelic in nature, the Flow experience is enjoyable and intrinsically rewarding. When people experience Flow, they are completely immersed in the activity, leaving no room for unrelated thoughts and emotions, therefore allowing efficient and effortless execution of the activity (Neuser, 2015). These analogies describe people's engagement with their mobile devices for different activities, which can be attributed to the affordances of the mobile device such as portability, flexibility, personalization, ownership and sense of control (Bressler & Bodzin 2013). In the educational context, Flow is associated with persistence in learning, characterised by a deep sense of control, engagement and enjoyment of learning (Park, Parsons & Ryu, 2010). The holistic sensation and deep engagement with the learning activity promotes motivation, skill development and better performance (Katahira et al. 2018). For students to achieve optimal experience and be in the Flow state, Csikszentmihalyi (1990) asserted that the activity must satisfy three conditions: *have clear goals*; *balance between the activity and skillset of those involved*; and *provide opportunities for immediate feedback*. Furthermore, Power (2013) argued that for students engaged in m-learning to experience Flow, in addition to balancing complexity, interest and opportunities for collaboration, the learning design should ensure easy access to the content. Power, argued further that, in order for students to focus on learning rather than the technology, they should be comfortable using their mobile devices, so as to ameliorate potential anxiety. Building on these arguments, this study, underpinned by the principles of social constructivism and Flow, investigates how cloud computing might be used as a pedagogical tool for m-learning. In doing so, it also proposes a potentially suitable cloud-based m-learning model for higher education in Nigeria, which may be applicable to other higher institutions with similar characteristics. Building on local assets and utilizing them in the proposed solution is likely to yield a competitive and cost-effective outcome. To explore how cloud computing might enhance m-learning, this study set out to answer the following research questions:

1. To what extent, if at all, does m-learning, delivered over the cloud, alleviate technological and infrastructural challenges?
2. To what extent did the m-learning activities foster collaboration, and conform to the optimal experience of Flow?
3. What impact did cloud-based m-learning have on students' experience of learning?

A PROPOSED CLOUD-BASED M-LEARNING MODEL

The cloud architecture consists of physical servers and switches which are the responsibility of the cloud service provider to run and manage (Khan et al. 2012). Given the limited IT infrastructure in universities of developing countries such as Nigeria, and for the purpose of this study the suitable cloud service model is the Software as a Service (SaaS). The SaaS model offers fully functional applications on demand, does not require any licensing, installations or configurations, and is launched directly from a browser (Simmon 2018). Correspondingly, the public cloud platform is considered most ideal because it also does not require any purchases, installation and maintenance, and provides access to the necessary resources and rich multimedia content (Harris

2010). Taking advantage of both platforms, a proposed cloud-based m-learning environment is presented in Figure 1. The backbone of the proposed model is the mobile network which has continued to improve since its inception in Nigeria in 2001 (Adepetun 2016). Using the services of any of the mobile network providers in the country, the clients (educators and students) can connect to the Internet using any embedded browser application from their respective devices, which in turn provides the gateway to access the resources of the cloud service provider. This would enable educators to upload content they create and for students to have access to the content.

In addition to the availability of the required technology, a comprehensive m-learning solution must be underpinned by purposeful design (Cochrane 2014), guided by relevant pedagogical principles that focus on student-centred learning, and seamlessly integrate the mobile technology and content to ensure meaningful learning (Laurillard 2007; Amhag 2016). Accordingly, the proposed cloud-based m-learning environment draws on theoretical principles to strengthen the course design. These include developing content that promote deep rather than surface learning, and providing opportunities for communication and collaboration (Kukulska-hulme & Shield 2008; Dyson 2012). Such collaboration may be achieved by integrating social networking platforms with which students are most familiar and comfortable, into the learning process. As noted by Sarwar et al. (2019), given millennials' digital awareness and exposure to social media, the integration of such platforms into the learning process promotes flexibility, and provides an avenue to foster students' interest and engagement in the learning activity. Figure 1 below depicts a learner-centred collaborative cloud-based m-learning environment, showing educators and students interaction with the cloud platform and each other via the mobile network. These processes in action are elaborated in the methodology section.

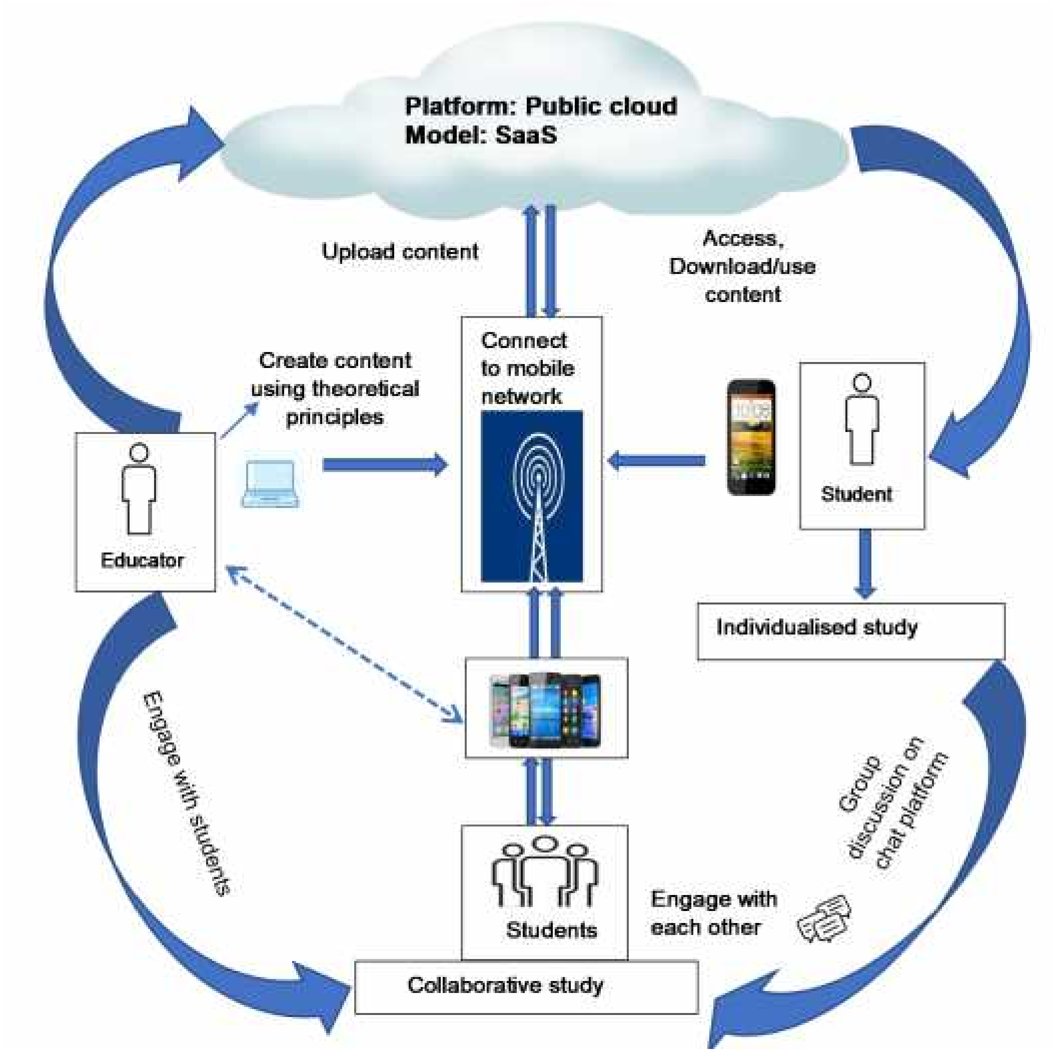

Figure 1: *A Learner-centred collaborative cloud-based m-learning model*

METHODOLOGY

The Case Study

The study was conducted in one of the state universities in Nigeria. At the time of conducting this research, and as is mostly the case at the university, Internet connectivity was poor due to inadequate infrastructure, insufficient bandwidth, and unstable electricity supply. Also, online learning management systems to facilitate teaching and learning, create personalised learning environments and sharing of academic resources were not in use. The norm at this university is the transmission of content through traditional didactic face-to-face lecturing, and when technology is used to facilitate teaching, it is at best a laptop and projector.

Participants

The researcher worked with two course lecturers and their students. One of the lecturers taught a Physics course (PHY 202) with 162 students and the other an Agricultural Science course (CRP 306) with 46 students bringing the total number of students to 208.

Learning Design and Tools

Important to the success of the trial was the need to develop m-learning opportunities that were modern and effective, and also considered contextual factors. Primarily amongst these factors was the need to keep cost to a minimum. To achieve these, a blended teaching and learning approach which combined m-learning with the traditional face-to-face delivery was adopted. The usual practice where the lecturer delivers a lecture to introduce a new concept was replaced in this trial with pre-recorded lecture videos created by the course lecturers. Videos were used because they are powerful instructional mediums that provide concept clarity, and when done objectively, can offer great value for time (Vieira, Lopes & Soares, 2014). The authors assert further, that instructional videos provide excellent support for self-learning and enhancement of the learning process. As noted, keeping cost to a minimum was a key requirement in this study. Therefore, all that was required from students was a simple mobile device with a web browser and Internet connectivity; while the course lecturers, in addition to a mobile device also required a laptop for video creation. The videos were created and hosted over the public cloud using screencast-o-matic. Screencast-o-matic is an online video creation, management and sharing tool owned and operated by a third party. It gives the user free recording of videos up to 15 minutes long, or a paid annual subscription of $US15 to record longer videos, and includes access to additional features such as video editing. Despite the consciousness to keep cost to a minimum, producing quality videos was also important. Therefore, the paid version was used for this study to take advantage of the video editing tools. Although screencast-o-matic provides flexibility to record anytime anywhere, given the broadband Internet connectivity issues at the university, the software was downloaded and installed on a laptop. This was to allow creation of the videos even without Internet connectivity. The created videos were then uploaded to the cloud using the modem from one of the mobile service providers in the country, while students accessed the videos using their respective mobile data bundles.

Another important tool used in this study was the WhatsApp chat messenger. The decision to use this form of social media was based on its popularity amongst students, and one that allowed for easy communication and collaboration among students, their course lecturers and the researcher. WhatsApp has also been widely reported as an effective platform to facilitate m-learning (Bere & Rambe 2019). Prior to commencing the trial, each class was visited by the researcher who explained the study to students and asked them to create chat groups. A total of three WhatsApp groups were formed, one for the Agricultural Science course and two for the Physics course. Given the potential of unrelated posts on the group chat, students were encouraged to have only discussions related to the course content. To ensure this and maintain the requirements of Flow (which include having clear goals), after the groups were created, the first post from each group administrator was the need to keep the focus of the conversations on the course content (an example is shown in Figure 2a). This was by and large achieved with students even helping each other to keep this focus, that is, when anyone introduced anything irrelevant to the course, students were quick to remind their peers of the goals, and in most cases an apology was quickly rendered (an example is shown in Figure 2b).

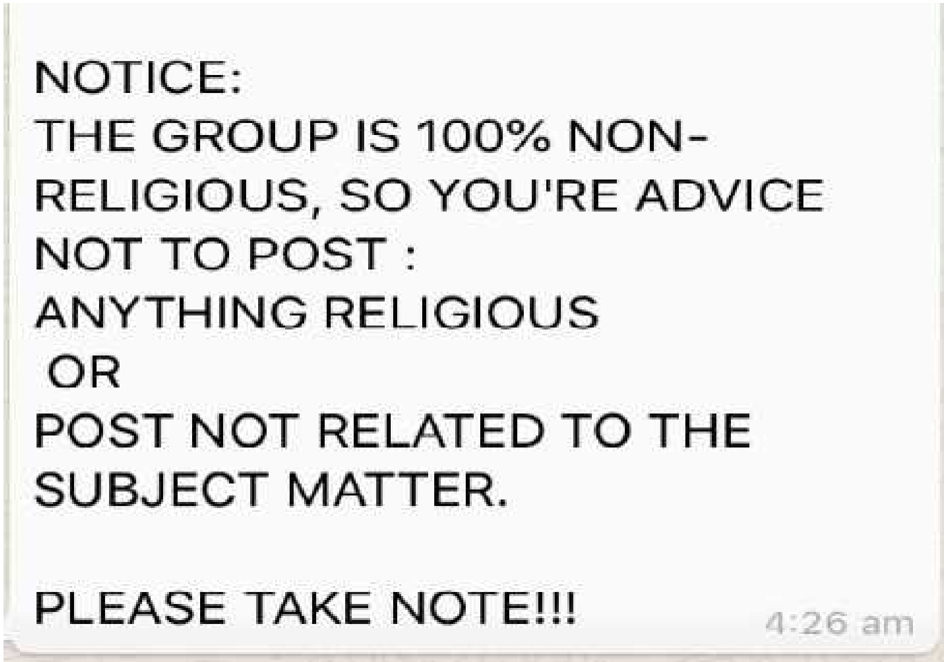

Figure 2a: *Initial group notice*

Figure 2b: *Reactions to a non-academic post*

Procedure

The duration of the trial was eight weeks and lecture videos based on power point slides were created. Each lecture video was approximately 15 minutes long. The length of the video was informed by several studies which suggested that to maximise students' engagement and promote active learning from videos, they should not be longer than 15 minutes (Buzzetto-More 2014; Koppelman 2016; University of Waterloo 2015). Additionally, it was thought that short videos would have a better chance of success in Nigeria where students rely on mobile data bundles. Long videos would be unfavourable as they would consume more data and ultimately be more expensive.

The content of each video was created following the principles of social constructivism and Flow. This meant that in addition to having clear goals, the content should be concise and engaging. In creating the videos, factors that may potentially lead students to achieving Flow were considered. Therefore, each video was made to achieve specific learning objectives, and the lecturers made efforts to present the content in ways that were both engaging and allowed for easy comprehension, sometimes using step-by-step guidelines. Screencast-o-matic offers three options for video creation: screen recording, webcam or both. For this study, both the screen recording, and webcam options were used (that is, power point slides were presented alongside the lecturer's face). After each recording, the video was first saved as an MP4 file and edited if necessary, before uploading to the screencast-o-matic platform.

Once uploaded, a link to access the video was generated, and shared with students via the group chat. Students were required to watch the videos first on their own, then discuss the content with their peers on the group chat prior to attending the face-to-face lecture, so they would come to class with knowledge allowing for further engagement. The course lecturers and researcher were also part of the respective group chats. While the lecturers responded to questions about the content and offered clarifications when necessary, the researcher was there to observe learner interactions.

Data Collection and Analysis

Data for this study were gathered using survey and observation techniques. The researcher closely observed activities on the group chat, and during the face-to-face class sessions. At the end of the trial, a paper-based questionnaire was used to collect feedback from students about their experience. Of the 208 participants, 143 responses were returned, representing a 69% response rate. The measurement instrument was a self-designed questionnaire, informed by the work of Abu-Al-Aish, Love and Hunaiti (2012). Most of the questions were on a five-point Likert scale, where 1 represented "strongly agree" and 5 "strongly disagree". These were presented as two sets of Likert scale items. The first scale contained 14 questions measuring whether cloud computing had any impact on infrastructural limitations as well as students' experience of m-learning, including the extent to which students perceived that they achieved Flow. The second scale contained 11 questions comparing students' attitude to m-learning before and after the trial. This scale was reproduced from the exploratory study (stated in the introduction), to determine if there was any significant difference in students' attitude to m-learning before and after an actual m-learning experience.

To determine the validity and evaluate the appropriateness of the instrument, the questionnaire was validated using the content validity technique. According to Bolarinwa (2015), content validity is the "degree to which an instrument fully assesses or measures the construct of interest" (p. 197), which can be determined through expert evaluation (Drost 2011). After the questionnaire was drafted, it was assessed by experts who confirmed the suitability of the instrument for the study. Reliability of the questionnaire was determined using the Cronbach's Alpha (α) reliability analysis which showed (α = 0.81 for the scale with 14 items and α = 0.72 for the scale with 11 items), indicating that the questionnaire was a reliable instrument (Tavakol & Dennick 2011). The questionnaire was analysed with SPSS statistics version 24 using descriptive and inferential statistics to report the emergent findings. Given that most of the questions were of the Likert scale type, the data were mainly ordinal, thereby making the non-parametric statistical tests most suitable for the inferential statistics. The non-parametric test used was the Wilcoxon Signed-Rank test to compare students' attitude to m-learning before and after the trial. Given that the questionnaire was paper based, it was inevitable that some questions were left blank. Even so, such questionnaires were not considered invalid because the majority of questions were answered. Therefore, while the total number of valid responses received was 143, the responses to each question varied slightly.

RESULTS

This section provides insight into how students engaged with the videos and their views on the impact of cloud computing on their m-learning experience. Over 80% of the respondents were between the ages of 18 and 25, and almost two-thirds were male (n=93; 65%).

The Impact of Cloud Computing on Infrastructural Barriers

The extent to which cloud-based m-learning helped to manage technological and infrastructural challenges was measured by students' ability to access the videos uploaded in the cloud, and the reported ease of access. The findings as illustrated in Figure 3 show that an overwhelming 90% of students agreed that having the videos online increased access to the content, and over 60% said access to the videos was easy. Those who identified difficulties accessing the content attributed this to poor connectivity, and the cost of data bundles to watch or download the videos. Students who could not download the videos on their own, received the files from their classmates via Bluetooth and Xender (a mobile file transfer and sharing app without mobile data usage). While this meant that the time to access the videos took longer for some students, it was the only solution to ensure that all participants received the content prior to class.

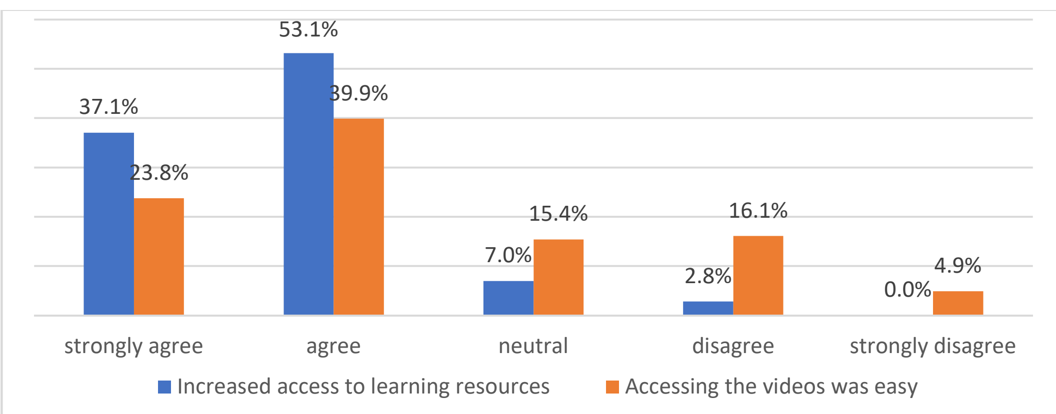

Figure 3: *The impact of cloud computing on m-learning*

M-learning, Collaborative Learning and the Flow Experience

In keeping with one of the core principles of social constructivism, that is, a democratic learning environment that promotes collaboration and interaction between students and with the lecturer, WhatsApp was used to facilitate such collaboration outside the classroom. The findings showed that the WhatsApp chat messenger impacted positively on students' m-learning experience through its ability to provide real-time interactive and collaborative learning opportunities. Students were able to ask specific questions, sometimes by taking a screen capture of the exact location on the video where they wanted clarifications. In many instances, when a student asked a question, their peers were quick to respond, offering their own understanding independent of the lecturer. An example of these processes in action is shown in Figures 4a and 4b respectively.

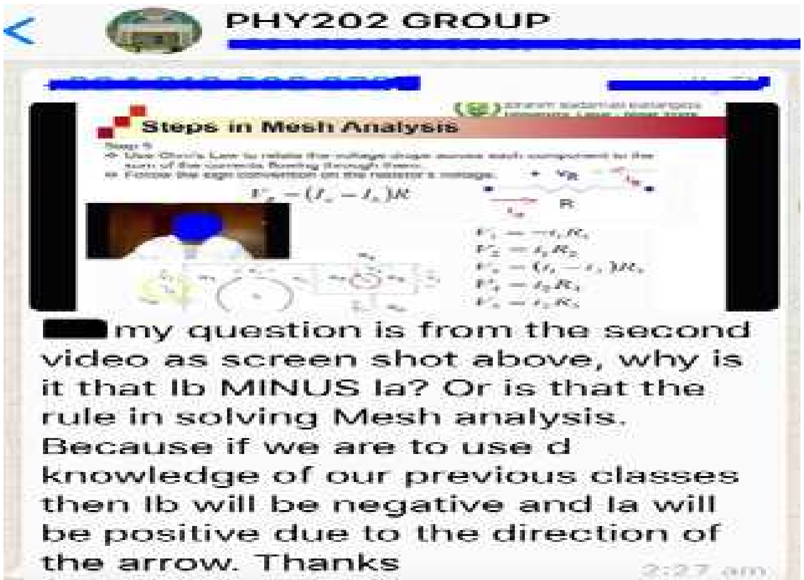

Figure 4a: *Screenshot of a student asking question*

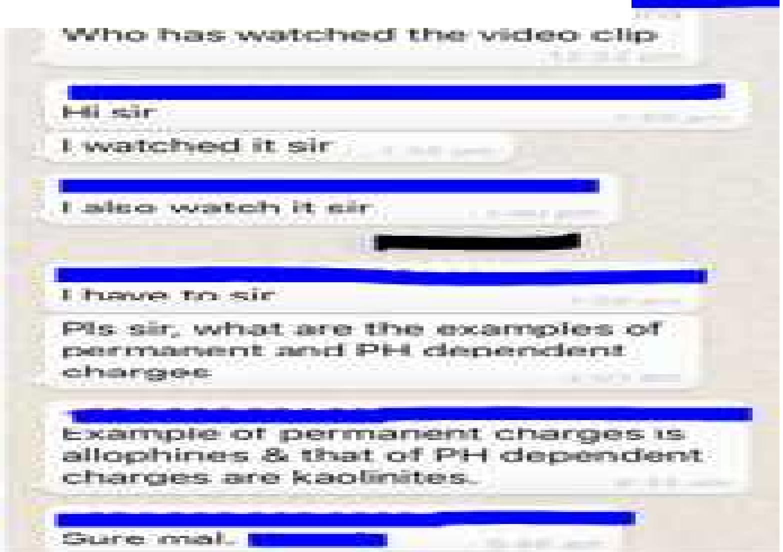

Figure 4b**:** *Collaboration on the group chat*

Determining the extent of Flow was measured by the degree of motivation, engagement and enjoyment students reported experiencing in learning with their mobile devices. The findings as illustrated in Figure 5, show that approximately 80% of students agreed that the videos were appropriate to their level of skill, that they increased their desire to learn and, were motivating and fun to watch. A cross tabulation found that 80% of students agreed that the videos were easy to follow and understand, and the opportunity to watch the videos prior to the face to face lecture, and collaborate with their peers on social media facilitated their understanding of the ideas when they later attended class. Despite the overall positive experience, 38% of students who did not agree on absolute engagement with the videos, that is, “always engrossed hardly realising how time elapsed” suggests that they may not have reached or had fallen out of Flow at some point.

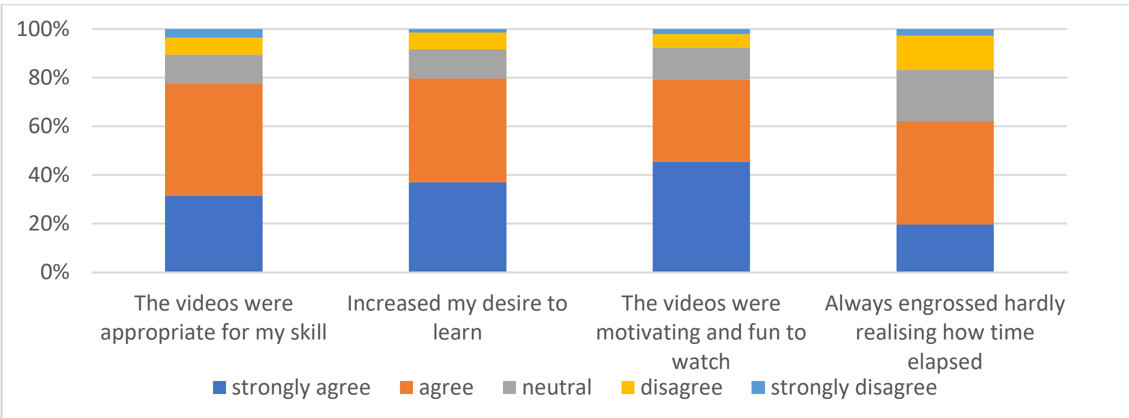

Figure 5*: *Students’ responses to Flow

The Impact of Cloud-based M-learning on Students’ Experience of Learning

The impact of cloud-based m-learning on students’ learning experience was determined using two variables. The first was by asking students to compare their learning experiences before and after their engagement with m-learning. The second was by comparing students’ attitude to m-learning before and after the trial. Findings regarding the first variable (see Figure 6 below), show nearly 90% of students reported that m-learning made learning easier and faster, while 73% indicated that they found it useful.

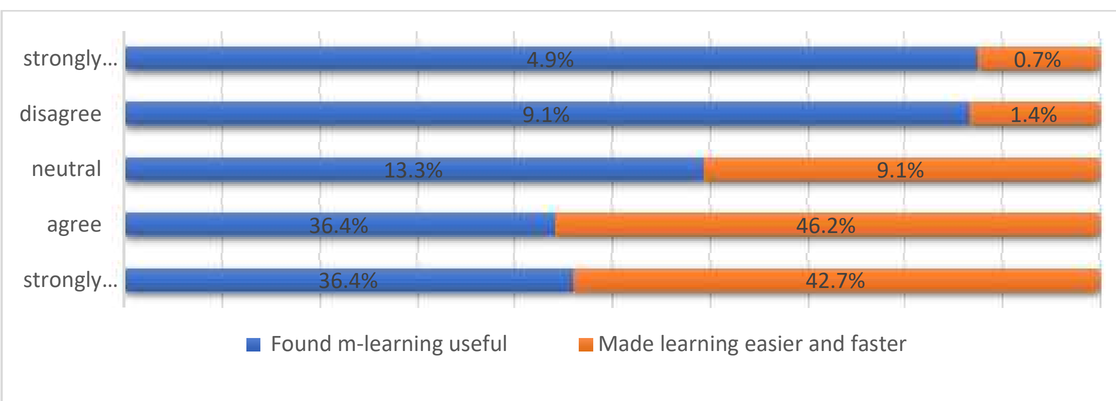

Figure 6*: *Students’ m-learning experience

As stated earlier, this study builds on the findings of an earlier exploratory study conducted to determine stakeholders' attitude to and readiness for m-learning. The findings of that study showed that students were optimistic about the ability of m-learning to promote "collaboration between students", "collaboration between students and educators", and "independent learning". Students were also positive that m-learning would meet their "learning needs and desires" (Okai-Ugbaje, Ardzejewska & Imran, 2020). Wilcoxon Signed-Rank test comparing students' responses to these four factors before and after the trial (Table 1) showed that students' optimism about m-learning in theory was also reflected in practice (no statistically significant difference (at $p \leq 0.05$) was found in all categories).

Table 1*: *Pre and post intervention results of students' attitude to m-learning

	N	Z	*p*	Median
Collaboration between students	138	-0.734	0.463	pre 6; post 6
Collaboration between students and educators	137	-1.062	0.288	pre 2; post 2
Independent learning	139	-0.176	0.861	pre 2; post 2
Learning needs and desire	129	-1.822	0.068	pre 9; post 10

DISCUSSION

Nigeria, like many developing countries with limited infrastructure, faces the challenge of providing quality IT services to students of higher education. As a result, the didactic approach with limited use of technology is most prevalent. The goal of this study, therefore, was to ascertain the impact of cloud computing in managing such limitations, as well as the reported impact that it might have on students' learning experience. In line with several studies (e.g. Bosamia & Patel 2016; Bouyer & Arasteh 2014; Karim & Rampersad 2017), the outcome of the trial showed that cloud computing offered many benefits including flexibility and convenience, and significantly reduced the time and resources needed to plan and implement m-learning. Additionally, the proposed cloud-based m-learning environment offered practical solutions to contextual problems. Despite the University's unstable internet connectivity, the public cloud provided a platform to upload the videos prepared by lecturers, and easy access to the content by students from anywhere and at any time. More specifically, the findings of this study align with the work of Naranjon et al. (2019), who reported "a barely zero cost" in using a public cloud-based educational platform to enhance learning in higher education, and that over 90% of students were "highly satisfied" and considered the cloud-based system an appropriate support tool for their learning.

Using the WhatsApp messenger as a supportive educational tool facilitated immediate feedback, cooperation and collaboration amongst students and with their educators. Students reported feeling a sense of belonging, with increased interest and motivation as they interacted with their peers. These outcomes are consistent with other studies, which also described the WhatsApp messenger as a platform that could help resolve learning problems and difficulties, and a tool for academic success if used appropriately (Ashiyan & Salehi 2016; Hassan & Ahmed 2018; Veena & Lokesha 2016). The positive experience of students and their reported attainment of Flow suggest that other important factors were at play in achieving Flow while engaged in m-learning include: (1) how learning is designed, especially opportunities for collaboration; (2) the mode of instruction, and (3) delivery medium that ensures easy access to the material. The outcomes of students' engagement during their personal study and collaboration over the WhatsApp group chats also translated into improvements in learning during the face-to-face class sessions. Time that previously would have been spent introducing a new concept or topic where the lecturer talks, and students follow passively became collaborative and interactive. This is corroborated by the findings of a systematic literature review by dos Santos et al. (2018), which showed that 22 out of 25 studies found student engagement with technology enhanced learning, underpinned by Flow led to positive outcomes. Despite the overall positive experience of the students in this study, the relatively low response regarding absolute engagement in comparison to the other factors suggests that students may not have reached or had fallen out of Flow at some point. According to Pearce (2005), to keep students in Flow requires using strategies such as the Flow State Scales (FSS) to track changes at relatively close intervals to ascertain when the challenge should be increased, thereby keeping the balance between new knowledge and the learning activity.

The impact of cloud-based m-learning on students' learning experience showed an overall positive experience. Students reported that the real-time acquisition and sharing of content promoted flexibility in learning, making it possible for them to share knowledge and have enhanced understanding of the course. This parallels the argument of Soon and Kadir (2017) who assert that using on-demand technology, learning over the cloud supports socially oriented and collaborative learning. Similarly, Chang et al. (2017) who examined the effect of cloud-based m-learning on students' performance found that there was significant improvement in students' creative process and innovation. The findings regarding students' attitude to m-learning before and after the trial indicated positive attitude both in theory and practice, and concurs with the work of Ozdamli and Bicen (2014) conducted to investigate students' perception of the advantages, appropriateness and adequacy of m-learning before and after a cloud-based m-learning experience. While the authors did not categorically report a positive or negative attitude in theory versus practice, it was clear that cloud-based m-learning provided a more effective learning environment which impacted positively on students' experience. Indeed, it is the movement from what is reported in theory, to what actually happens in practice that makes this trial and the reporting of the findings significant.

LIMITATIONS OF THE STUDY AND FUTURE RESEARCH

This study has provided a snapshot of the practical implementation of cloud-based m-learning from the perspective of a Nigerian university. While it is acknowledged that the duration of the study was short, it provides the basis for future studies to build upon. It is recommended that similar studies be conducted on a larger scale and for a longer period of time, with more academic subjects for more conclusive evidence. It would also be beneficial to consider using FSS during such investigations to ascertain when students may be 'running out of Flow'. This will allow lecturers to incorporate techniques to achieve increasing complexity as students attain Flow. In addition, to allow for deeper and richer engagement of students, both on the group chat and during face to face sessions, future studies may consider incorporating approaches such as the flipped classroom where students are divided into smaller groups.

CONCLUSION

This study moves beyond conjecture about the advantages of cloud computing and m-learning to establish practical benefits at a Nigerian university. While not all students in higher education in developing countries such as Nigeria have access to computers to facilitate learning, almost all have mobile devices. This makes it possible for higher education providers in these countries to leapfrog wired connectivity and move straight to wireless mobile technology. Skipping this generation of technology will also contribute to more pro-active measures for the environment (reducing CO_2 emissions) and 'Green ICT movement' to preserve the planet (Palanivel & Kuppuswami 2014).

The proposed cloud-based m-learning environment was found to be a cost effective and reliable option for content delivery. The findings of this study have shown that even when institutions do not have the resources to maintain stable internet connectivity on campus nor build their own cloud platforms, they can rely on public cloud offerings to facilitate effective teaching and learning with technology. This contrasts purported views that educational technology techniques such as video-based learning are expensive ventures and may not be sustainable in resource constrained countries (Boateng et al. 2016). In addition to enhancing the teaching and learning process, and improved learning experiences of students, cloud-based m-leaning also offered other benefits, such as the effective management and meaningful learning for large cohorts. In Nigeria, most lecture halls are overcrowded and not conducive to either teaching or learning. As demonstrated in this study, the proliferation of mobile devices amongst students indicates that cloud-based m-learning holds the potential to ameliorate this problem. It also provided a solution to the traditional practice of distributing lecture notes via the class representative who photocopies, and disseminates to the class. This sometimes leads to late delivery of the material or in some cases, non-delivery. Cloud-based m-learning ameliorated this problem, giving students access to the material as soon as it was uploaded by the lecturer.

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