# Educating Sub-Saharan Africa: Assessing Mobile Application Use in a Higher Learning Engineering Programme

Samuel Ikechukwu Eneje, B.Eng., M.Sc., MBA

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This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Department of Educational Research,

Lancaster University, UK.

This thesis results entirely from my own work and has not been offered previously for any other degree or diploma.

I declare that the word length of this thesis does not exceed the word count.

Signature ......................................................

Samuel Ikechukwu Eneje, B.Eng., M.Sc., MBA

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## Abstract

In the institution where I teach, insufficient laboratory equipment for engineering education pushed students to learn via mobile phones or devices. Using mobile technologies to learn and practice is not the issue, but the more important question lies in finding out where and how they use mobile tools for learning. Through the lens of Kearney et al.'s (2012) pedagogical model, using authenticity, personalisation, and collaboration as constructs, this case study adopts a mixed-method approach to investigate the mobile learning activities of students and find out their experiences of what works and what does not work.

Four questions are borne out of the over-arching research question, 'How do students studying at a University in Nigeria perceive mobile learning in electrical and electronic engineering education?' The first three questions are answered from qualitative, interview data analysed using thematic analysis. The fourth question investigates their collaborations on two mobile social networks using social network and message analysis. The study found how students' mobile learning relates to the real-world practice of engineering and explained ways of adapting and overcoming the mobile tools' limitations, and the nature of the collaborations that the students adopted, naturally, when they learn in mobile social networks. It found that mobile engineering learning can be possibly located in an offline mobile zone. It also demonstrates that

investigating the effectiveness of mobile learning in the mobile social environment is possible by examining users' interactions. The study shows how mobile learning personalisation that leads to impactful engineering learning can be achieved.

The study shows how to manage most interface and technical challenges associated with mobile engineering learning and provides a new guide for educators on where and how mobile learning can be harnessed. And it revealed how engineering education can be successfully implemented through mobile tools.

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would give up along the way. Not me, but we did it all. My heart is full of thanks, and I am truly grateful.

## Publications derived from work on the Doctoral Programme

A section of the thesis in chapter 4, that is section 4.3.4, is published in an academic journal, IEEE Explore[1], with the title "Engagement in a virtual learning on two social networks of an engineering course using the social network analysis - an approach using a case study". The first author is me, and the second author is the facilitator that prepared the setting for the research, and the third author guided me on representing the report using the descriptive statistics. I also tapped some amount of knowledge which reflected in my chapter two - Literature Review, from my previous publication[2] titled, "Real-world applications of mobile learning tools in engineering: prospects, hindrances and accessibility in conjunction with scholastic views".

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[1] https://ieeexplore.ieee.org/abstract/document/9255723

[2] https://ieeexplore.ieee.org/abstract/document/9255769

## List of Abbreviations

| | |
|---|---|
| App(s) | Application(s) |
| API | Application Program Interface |
| AR | Augmented Reality |
| BMAS | Benchmark Minimum Academic Standard |
| BYOD | Bring Your Own Device |
| CSS | Cascading Style Sheets |
| COREN | Council of Regulation of Engineering in Nigeria |
| EEE | Electrical and Electronic Engineering |
| FDD-LTE | Frequency Division Duplex-Long Term Evolution |
| FHD | Full High Definition |
| FOSS | Free and Open-Source Software |
| FUOYE | Federal University, Oye-Ekiti, Nigeria |
| GB | Gigabyte |
| GH | Gigahertz |

| | |
|---|---|
| GSM | Global System of Mobile Communications |
| GPS | Global Positioning System |
| HEI | Higher Educational Institution |
| HD | High Definition |
| HTML | Hypertext Markup Language |
| ICT | Information and Communication Technology |
| IEEE | Institute of Electrical and Electronic Engineers |
| iPAC | interactive-Personalisation-Authenticity-Collaboration framework |
| ITU | International Telecommunication Union |
| LMS | Learning Management System |
| mAH | milliamp hour |
| MA | Message Analysis |
| MELC | Mobile Engineering Learning Checklist |
| M-learning | Mobile Learning |
| MLEE | Mobile Learning in Engineering Education |
| MOOC | Massive Open Online Course |

| | |
|---|---|
| MP | Mega Pixels |
| MRLE | Mixed Reality Learning Environment |
| MS | Microsoft |
| NBTE | National Board for Technical Education |
| NUC | National Universities Commission, Nigeria |
| OEB | Online Educa Berlin |
| PC | Personal Computer |
| PDA | Personal Digital Assistant |
| PDF | Portable Document Format |
| PID | Proportional Integral Derivative |
| PSPICE | Personal Simulation Program with Integrated Circuit Emphasis |
| QR | Quick Response |
| RAM | Random Access Memory |
| RFID | Radio-Frequency Identification |
| SIWES | Student’s Industrial Working Experience Scheme |
| SMS | Short Message Service |

| | |
|---|---|
| SNA | Social Network Analysis |
| SNS | Social Network Site |
| TA | Thematic Analysis |
| UTAUT | Unified Theory of Acceptance and Use of Technology |
| UX | User Experience |
| VR | Virtual Reality |
| WPS | Word Processing Software |
| ZPD | Zone of Proximal Development |
| 2D | Two Dimension |
| 3D | Three Dimension |
| 2G | Second Generation |
| 4G | Fourth Generation |
| 5G | Fifth Generation |

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# Chapter 1: Introduction and Background

## 1.1 Overview

This chapter covers the research context, aim and purpose of the research, research setting, theoretical framework, research questions, research approach, ontological and epistemological stances in relation to the theoretical framework, proposed audience, stakeholders, and overview of the thesis.

## 1.2 Research Context

The need for mobility of learning has prompted the need for an innovative virtual learning solution that can complement emerging digital technologies (Jin, 2009). For developing countries, mobile technology is a leading and emerging technology of future learning (Al-Mashhadani & Al-Rawe, 2018), and engineering education, my professional area, has a stake in it. Mobile technology has been part of the supportive equipment in harnessing engineering education (Herrera et al., 2015, p.1157). Places where there is a lack of physical laboratory equipment can supplement with virtual laboratories using mobile learning (Johnson et al., 2013, p.6). Mobile learning is the use of mobile devices to deliver content and activities in which learning can be situated in a broader way (Kukulska-Hulme & Traxler, 2013; MDPI, 2019, p.2; Traxler, 2007).

This research focuses on a higher education institution in Nigeria – FUOYE. Many critics have attacked the incompetence of engineering graduates from

Nigerian local universities of which FUOYE is included (Babatope et al., 2020, p.35; Eboh, 2018). Good professional practice after higher education can reveal the quality of engineering education (Royal Academy of Engineering, 2012, p.4). Operating companies are searching for skilled engineering graduates for their core technical depth. Through Students Industrial Work Experience Scheme (SIWES) (Oyeniyi, 2012), most institutions within Nigeria have dedicated a lot of time and effort on how to integrate and train students to be effective engineers (Babatope et al., 2020, p.37). Babatope et al. (2020) mention two categories of engineering graduates, the expert and unskilled. Oyeniyi (2012) decried this misfit with engineering practice resulting from deficient skill development. Graduate engineering students are expected to have the skills required for professional practice, therefore training in these skills is necessary both in the university setting and the place of industrial practice to support these technological innovations (Babatope et al., 2020). Innovation in 21st century education is where the 3 R's (reading, writing and arithmetic reasoning) meet the 4 C's (creativity, critical thinking, communication and collaboration) (Babatope et al., 2020, p.37; Kolk, 2011).

FUOYE as an institution, just like other universities in Nigeria offering engineering degrees, has been far away from providing credible engineering education and fulfilling the needs of industry.

In the same vein, in a survey conducted in five sub-Saharan African countries, 40% of professional engineers stated that engineering learning in their country did not provide graduates with the required skills (Royal Academy of Engineering, 2012, p.6). One of the causes of this setback is insufficient equipment for engineering education which has pushed students to learn via mobiles (Idris & Rajuddin, 2012, p.733).

Mobile learning provides a variety of options to select and adopt, ranging from software, hardware, languages, architectures, and designs, bandwidth, or signal spectra, with or without internet, to accomplish a wide range of learning practices (De Witt & Gloerfeld, 2017, pp.3-12). There is immense use of mobile devices by engineering students across all Nigerian universities, just like in other disciplines, as students use them to engage in learning activities (Shonola et al., 2016, p.45). Mobile technology is the most affordable 21st century technology within sub-Saharan Africa, particularly in Nigeria. High use of mobile technologies in the region was revealed by James and Versteeg (2007) and the International Telecommunication Union (2019, p.8), see Figure 1.1, thereby providing more opportunity for mobile learning. James and Versteeg (2007) emphasised that society and interactions within it contribute to an individual's adoption of mobile technology. The background context in Nigeria has created a totally new behaviour among people, such that they use mobiles to learn anywhere, anytime. Mobile technologies have dominated many aspects of life and human endeavour, including adoption in education; however, with no defined plan, it appears to have been occurring in a haphazard manner (Brown, 2003).

Students support their education using the mobile tools at their disposal. Neither mobile learning nor e-learning have had a firm grip in the Nigerian education sector especially engineering. So, engineering students are facing a dilemma; one is that there is not yet an established structure for virtual or mobile learning to supplement inadequate laboratories. However, since the evolution of smart mobile devices, more and more students have chosen to adopt mobile tools for smart learning and to practice skill development (Punithavathi & Geetha, 2020, p.788). Since mobile tools are becoming more affordable, students are increasingly using mobile tools to learn today in Nigeria (Shonola et al., 2016). What matters, is how mobile learning is contributing to their education, or not? Has it helped in developing expertise? How challenging has learning with mobile tools been? What are their experiences? Does their experience match the needs of real-world professional practice, or not? Is the mobile learning that they do just scratch on the surface or is it deep and impactful? Does mobile learning contribute or impede knowledge acquisition and developing expertise in engineering professional excellence? Finding the answers to these few questions is the starting point for improving mobile learning frameworks for engineering across universities.

If we must consider using a technology for learning, then it is helpful to understand the interaction between users and mobile technologies, i.e. how and what are the users' experiences (Sung et al., 2016, p.255). Previous cases suggest that understanding the effectiveness of engineering education (skills and knowledge) using mobile tools, when users use them to develop themselves, is appropriate (Punithavathi & Geetha, 2020, p.789). Examining the students' mobile learning experiences as they move from first to fourth year, and to industrial practice during the SIWES could help in knowing what approach might be employed in harnessing the much-needed innovation in engineering education, to evade the total institutional dependence on physical laboratory equipment of which they never have enough.

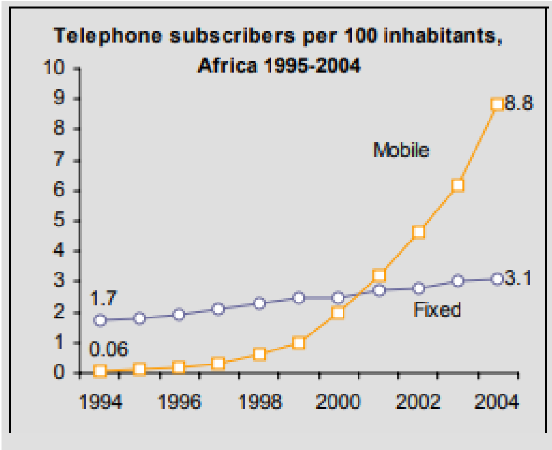


Figure 1.1 International Telecommunication Union`s indicators of rise in mobile over fixed broadband in Africa. (Source: extracted from ITU, 2006, p.2).

### 1.3 The Aim and Purpose of the Research

Mobile learning is an emerging field of technology-enhanced learning and has been viewed differently by many diverse scholars based on their distinct perceptions from which they proffer recommendations (Kumar & Mohite, 2018, p.3). There have been thoughts about supplementing inadequate physical laboratories in the Higher Educational Institution (HEI), with mobile learning facilities (Yates, 2003, p.134). Mobile learning and its technologies have become a leading piece of new ICT innovation for learning (Keegan, 2002, p.9). To meet the demands of innovation that are sweeping across engineering fields new approaches in mobile tools use are necessary as engineers of the future are required to be thoroughly equipped with the power of modern technology and competence to interpret and transform a virtual to a real-world experience (Löwgren & Stolterman, 2007, p.3). Understanding learning approaches through the continuum of mobile learning tools will be helpful in concretising how and where mobile technologies can be used in engineering.

Doing engineering is complex and involves practising tough tasks such as scientific manipulations to proffer solutions to highly technical problems (Alqudah & Al-Qaralleh, 2012, p.32). Accomplishing this feat is possible with customised and frequent use of mobile devices. Finding reliable information about what is possible with mobile tools and what is not is attainable through users (McCarthy & Wright, 2004). Universities rely solidly on students as agents of educational technology policy making (Czerniewicz & Rother, 2018, p.32), because the experience of end users, i.e. the students, is extremely important to the success of mobile learning adoption (Ali et al., 2014, p.2).

Since the advent of mobile learning by students of FUOYE, gathering student perceptions for the purpose of drafting future policies has been wanting. Neither has this kind of study been done in FUOYE nor in engineering departments elsewhere, as it is novel research that hopes to educate and enlighten educational technology policy at most universities of the Sub-Saharan African region that are characterised by poor infrastructure for learning.

This study investigates the mobile learning of engineering students in FUOYE. The research aims to find out the students' approach and prospects in adopting true engineering practices that are transformable to real practice situations, aiming to enhance engineering education practice. And, to discover what adaptations were required to harness performance of technical tasks over mobile devices. To achieve this, I deeply narrowed the search using one aspect of engineering, and the main inquiry statement asks, how do students studying at a University in Nigeria perceive mobile learning in electrical and electronic engineering education?

### 1.4 The Research Setting

The research is conducted in FUOYE[3] engineering department. FUOYE is a university in Sub-Saharan Africa. It is an emerging giant among over forty-two federal universities in Nigeria and is one of the last sets of established universities owned by the national authority. The university has strong programmes in many disciplines across the Engineering Faculty such as mechatronic, mechanical, computer, and electrical and electronic. This research is narrowed deeply into electrical and electronic engineering. However, the outcomes of this study can be applicable to other engineering fields. All the engineering departments have commonalities (see Figure 1.2).

The general engineering education occurs in the first two years, with specialisation in years 3-5, with a requirement to engage in practical workshops and industrial workplace placement.

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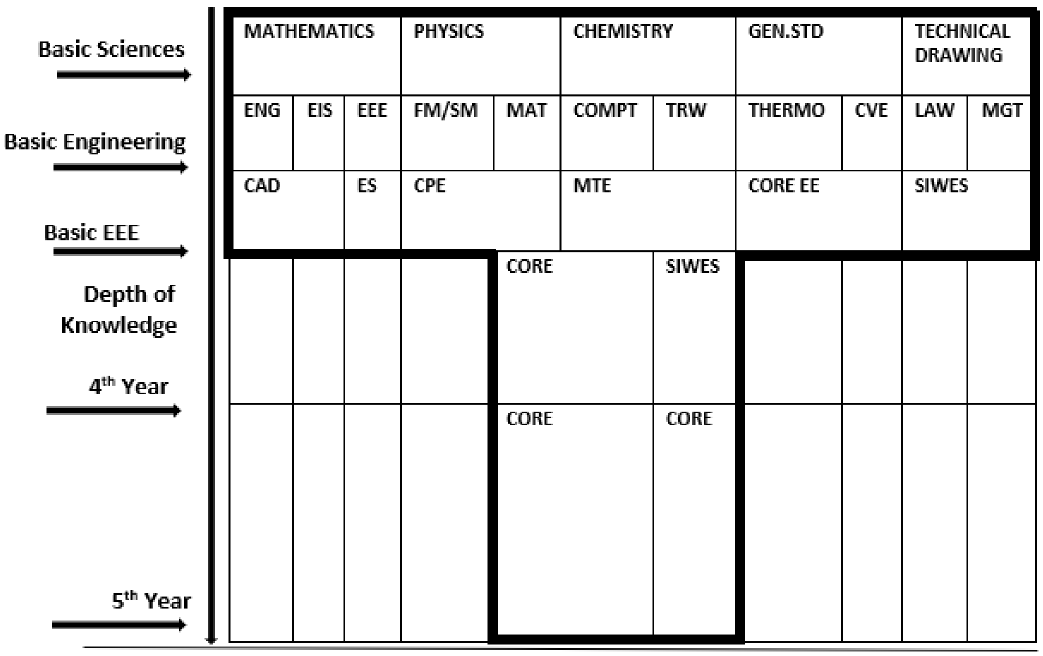
[3] https://fuoye.edu.ng/




**LEGENDS: GEN.STD- General Studies, ENG-Engineering Mathematics, EIS-Engineers in Society, EEE-Electrical and Electronics Engineering, FM-Fluid Mechanics, COMPT-Computer programming, CPE-Computer Engineering, MTE-Mechatronic Engineering, CVE- Civil Engineering, MAT- Material Engineering, TRW–Technical Report Writing, THERMO-Thermodynamics, ES-Engineering Statistics, WKS-Workshop, LAW-Law, CAD-Computer Aided Design, MGT- Management, EE-Electrical and Electronics, SIWES-Students Industrial Work Experience Scheme.**

Figure 1.2 The structure of undergraduate engineering education (adapted from Babatope et al., 2020, p.36).

The SIWES is a mandatory industrial placement programme during which an engineering student goes into industry to gain work experience and demonstrates their four-year knowledge. It is incorporated into the academic programme (Babatope et al., 2020, p.37; Omonijo et al., 2019, p.162). Every graduate engineer is expected to be fully knowledgeable and skilled as an engineer who possesses the following (Yrjänheikki & Takala, 2001, p.46):

- a solid basic knowledge of engineering science,

- an in-depth knowledge of the engineer`s own field of technology,

- capacity to solve problems creatively,

- willingness to develop oneself and the quality of engineering work,

- ability to demonstrate the crucial expertise that can match one`s leadership role in industry in a changing environment.

However, accomplishing these prerequisites is not merely achieved through teaching but through regular self-practice by the students. Mobile learning offers individualised learning and facilitates creative laboratory learning for engineering programmes (Zarei et al., 2017, p.3).

### 1.4.1 Mobile learning adoption during emergency remote teaching at FUOYE

Most students use mobile tools to supplement traditional classroom learning. Despite the critics, the impact on learning is highly important since hands-on skills are essential to engineering practice. Students have not relied, so much, on the University’s inadequate infrastructure for their academic success, but have made high-use of mobile technologies. Due to the COVID-19 Pandemic, recently, emergency remote teaching has led them to appropriate mobile technology use in learning skills for real-world practice. The real-world experience means learning engineering authentically using tools in such a way that practice is professional especially in solving problems (Massimi et al., 2007).

A major adoption of the mobile tool is for communicating among users and online inquiries. The objects are not generally declared as an educational intervention agent, however, mobile tools were adopted during a temporary and accidental closure at FUOYE by the local authority in 2018. The remaining period of the academic session was completed with mobile tools, and instructors were communicating with their students, using mobile social technologies such as WhatsApp, Facebook, WeChat, and mobile applications. Academic shutdowns in FUOYE are a regular occurrence, just like in many government owned institutions in Nigeria, orchestrated by either workers' industrial strike or election clamp down. The length of closure has varied from 2 months to one year. In such times, students resort to mobile learning. Even in that pitiable condition, these universities always graduate their students each year with the little they have learned. However, there is no evidence yet on how impactful mobile learning has been in delivering real professional engineering skills and the knowledge they require.

A similar scenario was described by the Royal Academy of Engineering (2012, p.4) and they called for improvements in engineering education at the tertiary undergraduate level (Abbott et al., 2019, p.45). As an instructor in the faculty of engineering, I have first-hand knowledge of massive use of mobile learning by my students. However, the question remains as to how much it is impacting on learning. Adedokun (2011) decries poor engineering education in Nigerian universities resulting from inadequate laboratory equipment (Idris & Rajuddin, 2012, p.732). And, statistics show that the student-to-equipment ratio was 20 to 1 before 1999 and in this decade the ratio has escalated to 70 to 1, indicating a cluster of more students than available laboratory machinery for accomplishing skill acquisition (Akintola et al., 2002, p.395). Students could supplement, for poor or missing laboratory sessions, by practising virtually with the mobile versions that are deployable on their mobile phones since mobile-based solutions can help to compensate for lack of a physical laboratory (Grimus & Ebner, 2013, p.2028). Therefore, the future of learning in developing countries such as Sub-Saharan Africa is mobile (Vosloo, 2017).

### 1.4.2 Connecting to emerging mobile learning technologies

It is stated that by 2025 nearly everyone on the planet is expected to have access to an internet-connected mobile device (UNCTAD, 2018, p.7). In Nigeria and neighbouring countries, mobile penetration has been found to be growing at a phenomenal pace over the past five years and the mobile subscription exceeded 130 million as far back as 2007 (Haji et al., 2013, p.3). Taking advantage of the avalanche of mobile penetration offers potential to deliver effectual and standardised learning practices that equal real-world practice (Abhyankar & Ganapathy, 2014; Astatke et al., 2015; Massimi et al., 2007; Nagata et al., 2017; Sarrab, 2015; Wanyama, 2017), by surmounting all existing limitations surrounding online learning (Broadbent & McCann, 2016), such as in use of:

- mobile tools for learning publicly via video uploaded to sites and social media channels, e.g. YouTube, CORE-Materials, Coursera, FutureLearn.
- LMS sites to moderate online engineering learning, resources disseminated or used in virtual learning environments and MOOCs.
- mobile and desktop applications, e.g. Arduino, Simulink.

- toolbox and virtual material laboratories, e.g. https://expeditionworkshed.org/materials/

There are many evidence-based examples underpinning the adoption of mobile learning in electronic and computer engineering, without disruption. For example, Avanzato (2001) documented that second year engineering students used an application provided with mobile devices for collaborative learning activities. In addition, Mckeown (2004, p.2235) documented learning through the adoption of tablet devices integrated into a Visual Basic programming course. However, critics against the adoption of mobile technology in engineering education came before the modernisation of the mobile transmission channel and frequency, and criticism centred on the mobile device`s operability in terms of small size, and slow speed of sending commands and retrieving responses (Parsons et al., 2006). However, the good news is that the sophistication of most mobile devices and bandwidth channels have improved in the last few years. For instance, the architectural combination of Tablet and Cellphone in the form of ‘Phablet’ offers a large screen for visualisations and responsive handling. Also, the massive input and massive output frequency allocation operated on mobile signal transmission has overhauled the old scheme with an improved speed. The technological change sets new hardware every half-decade (Passey et al., 2016, p.127). The total supply of spectrum is fixed, but technology being used is what affects the extent to which it can be utilised and enjoyed in content delivery. The full spectrum ranges from 9KHz to 300 GHz. According to the principle, the higher the frequency of signal, the lower the distance of propagation, but the higher the signal’s data-carrying size. This fundamental characteristic of the signal spectrum hinders the range of applications, i.e. content delivery, for which any specific band is fit, although some part of the spectrum (such as in the Ultra-High-Frequency band, 300-3000 MHz) are appropriate for a wide variety of services and is thus in great demand, such as cellular mobile networks (ITU, 2006, p.1). The frequencies of operation licensed in most Sub-Saharan countries are around 800 and 1950 MHz. According to ITU, there have been modifications in allocation of frequencies to countries because of policy changes and rising demand for service. For instance, Nigeria`s figure is tolerated at 3G, presently compared to 1G or 2G that was used in the past when there wasn`t yet room for expansion of mobile networks (ITU, 2019; Spectrummonitoring, 2019). Invariably, mobile networks have expanded around the vicinity where students of FUOYE live. These changes have made most previous literature published, which criticised, and hallmarked the incompetency of mobile learning in this region, null and void or at least, questionable. Therefore, it is important to review the current state of adopting mobile technologies in engineering education especially in a part of the world where capacity is still developing.

## 1.5 Theoretical Framework

This section discusses the theoretical framework and its constructs used to undertake this research study. It also covers other theories adopted in sieving relevant data.

### 1.5.1 Mobile learning pedagogical framework

The mobile learning pedagogical framework (Kearney et al., 2012) uses learning activities in location and time to provide a nuanced interpretation that describes and articulates the underpinnings of quality mobile learning and pedagogy (Schuck, 2015, p.2), see Figure 1.3. The emerging pedagogical dimension focuses on authenticity, personalisation, and collaboration and the convergence of the trio is enabled by use of time and space (Petit & Santos, 2014, p.5).

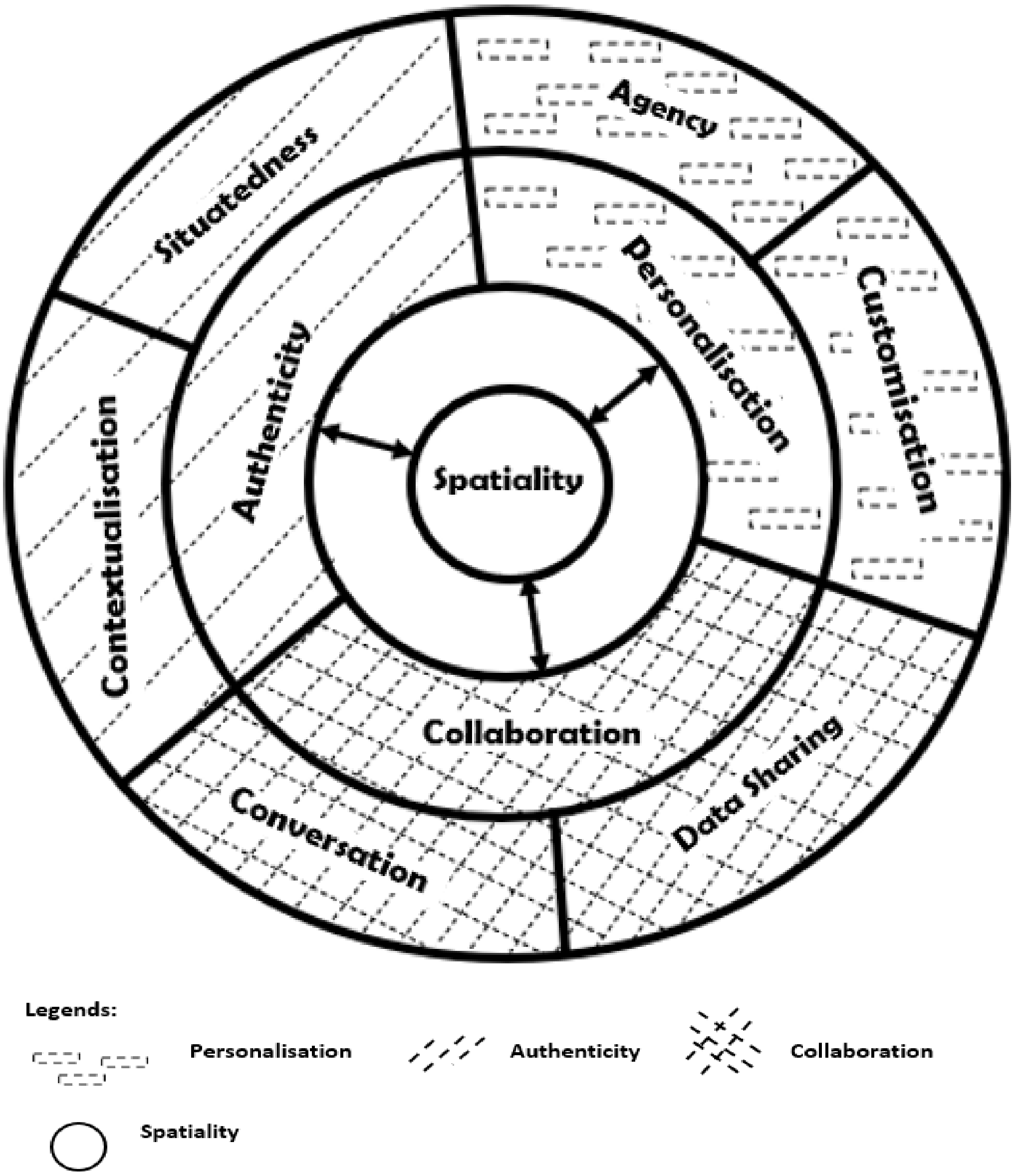



Figure 1.3 Mobile Learning Pedagogical Framework developed from Social-cultural theory by Kearney et al. (2012).

In view of the nature of the engineering case this study intends to investigate, adopting Kearney et al.'s (2012) version of the mobile pedagogical framework is deemed to be the most suitable option because this research focuses on students. The interactive-Personalisation-Authenticity-Collaboration (iPAC) framework tended more towards providing a tool for viewing the mobile pedagogies (Kearney, et al., 2019). More so, iPAC as it was derived in the non-engineering field, considers the laptop as a mobile device, but in engineering this is disputed (Ashfaq & Sirshar, 2018; Choi et al., 2014; Eneje, 2020, p.4). The uniqueness of the mobile tool used in the engineering field led me to undertake this thesis using the fundamental framework that was derived from a socio-cultural perspective. However, this does not negate the relevance of the iPAC framework (Kearney, et al., 2019) in studying mobile learning.

#### 1.5.1.1 Authenticity

Practical or participatory learning is a leading activity in engineering (May & Strong, 2011, p.211). It provides real-world relevance and personal meaning of the activity that is being carried out, to the students. Many scholars view authenticity differently; Radinsky et al. (2001) state that authenticity is the degree to which students, not instructors or curriculum designers, map their learning activities to the external world. Hiebert et al. (1996) view authenticity as the extent to which a student can problematise the subject matter in a learning activity.

Kearney et al.'s (2012) model focuses on the meso-level, which is on the mobile learner's experience. Meso-level, micro-level, and macro-level are the three levels of viewing the pedagogical perspective of mobile learning. And the meso-level focuses on students' experience and communication, micro-level on usability, and macro-level on integration of mobile tools in an organisational context (Vavoula & Sharples, 2009).

Authenticity is explainable using three categories: task, tool, and setting (Kearney et al., 2019). The task is the engineering practice students do, practice, or learn. The tool is the type of mobile tool they use to do tasks, and the setting is the place of application of their expertise, where the practices are used, deemed relevant, or acceptable as a problem-solving culture.

Also, the three contexts of unpacking authenticity, according to Burden and Kearney (2016), are viewing it from the participatory, simulated, and hybrid contexts. Participative authentic context refers to when students participate in genuine real-life communities. It is when engineering learning is authentic because it is situated in the same context that it will be used, making it personally meaningful for the student. Simulated refers to the replicating real-world engineering process of tasks using the mobile tools. And in hybrid, both simulated and participatory contexts are viewed as vital in realising genuine real-world practice. Learning that is of a hybrid complexion combines features of both an explicit participative and implicit simulated form of authentic learning and many of the technology projects which have explored these spaces reveal that the students use all the relevant qualities of simulations with the additional benefits of high ecological validity acquired through participation in a genuine community (Burden & Kearney, 2016).

Authenticity was described in an experiment similar to learning engineering practice by the trio of factual, task or process levels of authenticity. Factual authenticity discusses how specific details of a task (such as codes, characters, algorithms, instruments) are like the real world. Task authenticity discusses the scope to which tasks are realistic and offer problems met by real-world engineers, while a process's authenticity refers to how students' practices are like those practices carried out in the community or 'real-world' practice (Cognition and Technology Group at Vanderbilt, 1991; Kearney et al., 2012, p.9).

Many underlying factors contribute to a student's ability to actualise authenticity in mobile learning. Radinsky et al. (2001) reveals that cultural value differences (risks and opportunities) may thwart authenticity. This is because bringing together a higher education institution and a corporation into a joint venture with the purpose of improving students' skills using SIWES may reveal differences in practice.

Authenticity focuses on the relationship of engineering or education activities to professional practices. The need to strike the balance had promulgated the adoption of SIWES in all engineering learning institutions, including my university. SIWES is an internship that takes from three to twelve months of practice plus mentoring, coaching, training, and tutoring of engineering students in industry. This learning structure called SIWES contributes knowledge, skills, ethical experience, technical new culture, and moulds future engineers for their careers.

This research draws on the extent to which tasks are realistic and can handle real-world engineering techniques in solving issues, covering how a particular activity's information is accomplished with a tool, and how their practices are like those practices carried out in 'real-world' engineering practice. For instance, a power engineer deals with a sub-field of electrical engineering that encompasses the generation, distribution, and utilisation of electric power, and deals with equipment that aids this process such as transformers, generators, electronics, and electric motors. In a similar fashion, student power engineers can view and work with these non-real models of equipment in a mobile learning environment thereby enabling the students to engage in practices using the real equipment without the need to be concerned about their safety, e.g., safety related to high-voltage equipment.

There is learning emanating from the work setting in mobile social spaces (Attwell, 2010). If an argument starts with a demonstration that knowledge has a contextualised character, then it implies that we cannot separate knowledge to be learned from the situations in which it is used (Pimmer et al., 2010, p.8). The idea of 'situated knowledge' invites the equivalence of knowledge as an implement (Laurillard, 2001, p.14). Brown et al. (1989) argue that we must use acquired knowledge in an authentic way, i.e. genuine application of the knowledge, which allows students to build an increasingly rich understanding of the tool itself and how it operates. Laurillard (2001) suggests that students must learn from a situated perspective. This is common practice in all engineering courses and has its parallel in every other kind of course. However, problems arise from the scope of "authentic", the degree of embeddedness in the social and physical world, in the real practice of engineering (Laurillard, 2001, p.15).

The contextual tasks, from setting, character, and tool used, involve real-life practices but how realistic or relevant are the practices of learning (Kearney et al., 2012, p.10)? Contextualised learning constitutes in the lived-in-world, that is, the world as it is experienced in the social practice that shapes knowledge and knowing, and with students gradually able to master procedures for doing tasks. It considers the concordance of students' current practices to the historically developed repertoire of practices, whose meaning, procedure, and significance is repeated, done and reproduced in situ (Pachler et al., 2009, p.169). There could be evolving and changing social, technological, and cultural practices of students' approaches to tasks; the reality of conformity to processes and facts enshrined in the context remains unwavering. This construct views experiences, in single practice, groups or communities, in knowledge building as questions pertaining to situatedness and contextualisation.

#### 1.5.1.2 Personalisation

In mobile learning systems, personalisation is the process of enabling the system to fit its behaviour and functionalities to the learning needs, personal characteristics, and particular circumstances of the individual or a group of collaborating students (Khalfallah et al., 2014, p.20). This construct enables this study to interrogate the key features that are related to personalisation and these are the students' choices, agency, and self-regulation during learning as well as customisation (McLoughlin & Lee, 2008, pp.12, 14).

According to Suárez et al. (2018, p.40), agency refers to the ability or capacity to take control of one's own learning (Benson & Kong, 2007), or to refer to the capacity to act with initiative (or self-regulation) and affect one's own learning. Amidst arguments, there is no conclusive meaning of agency other than what students' motivational and metacognitive abilities can adopt to attain learning objectives (Suárez et al., 2018, p.40). That implies that students use agencies that they perceived can work for them during personal or collaborative learning. Personalisation has strong implications for ownership, agency and autonomous learning (Kearney et al., 2012, p.14).

If the kind of freedom or choices that the students have in mobile learning facilities are great, then they may have high levels of agency. Otherwise, they will have low agency. Students tend to have autonomy over content. And it will be insightful to know, through this study, the circumstances that enable autonomy. When is it likely that a student will assume autonomy, based on their background? This study helps understand how familiar the contents are to the students and the creative skills that aid them in customising learning over time.

Traxler (2009) indicates that diversities, differences and individualities are identified in personalised learning and are adapted to each student differently. This implies that each student creates a way to adapt and customise learning and practice (Kim et al., 2013, p.55). Content adaptations among others are highlighted as personalisation approaches by Marin and Mohan (2009). This study investigates how students create means of achieving learning where mobile tools permit engagement in self-directed activities, and as students exercise agency in moving beyond simple participation in the search for knowledge to become active creators of ideas, resources, and knowledge artefacts. The skill sets that students have, such as creation, inquiry, critique, analysis, and networking, are seen as vital in the new knowledge economy, which leads to creativity (McLoughlin & Lee, 2008, p.14).

Agency helps students to have self-efficacy (Ma et al., 2016), i.e. belief that they can accomplish tasks without help. Agent tools and abilities may vary significantly depending on the roles that they take in their deployed environments. In mobile infrastructure, agent is an entity that can convey flexible autonomous activities in an intelligent style to accomplish tasks that meet its design objectives, without persistent intervention by the student (Edein Qoussini et al., 2015). However, agency is a way through which agents support personalisation (Edein Qoussini et al., 2015, p.17). Outside infrastructural design of mobile tools, a student uses agency to process information locally and direct the task so that their learning goal is attained (Edein Qoussini et al., 2015, p.22).

#### 1.5.1.3 Collaboration

Interactions evolve in various forms creating learning opportunities in a broad-based, multi-sourced, context-based, integrated form of information conveyance.  Social constructivism suggests that students learn ideas or create new meaning when they interact with others and with their world, and through interpretations of that world by actively constructing meaning. Interaction cannot exist in isolation; they are evinced through socialising in the digital world. Learners relate new knowledge to their previous knowledge and experience (Frank et al., 2003, p.274). The level of human interdependence in the digital world has helped evolution of new technologies. Human lives seem to continually focus on technologies that expand human potentialities and connect them with other members of their society. In contrast to other perspectives, some technology users believe that technology has drastically modified the way humans do things and interact, and will certainly rule the world (Peia, 2010).

Evidence of knowledge transfer and skill acquisition transpiring among engineering students that are in a continuous interaction in a mobile tool or mobile social network comes from either how technology influences learning (i.e. using mobile tools to do quickly the task they used to do manually) or how technology changes for their common interest (i.e. cope with upgrade of versions of mobile tools without stress) (Ansari & Khan, 2020, pp.1-2).

According to Nerantzi (2018, p.328), online engagement with mobile tools could appear in two patterns, and this was included in a framework associated with collaborative open learning; they are ‘selective collaboration’ and ‘immersive collaboration’. These two patterns reflect collaboration as engagement in learning. Various contexts develop learning conditions where students engage with knowledge together. Shaping technology influences create engagement variations that depict the presence of selective and immersive forms of learning. The social constructionist’s view would anticipate that it is worth understanding what conditions, influences and environments are overcome to shape how their use of technology enables access to mobile learning even in the interactive mobility space.

There is a connection between the collaboration in learning and social interaction among students (Pivec & Dziabenko, 2004, p.19). Social structures assume two-way exchange of information (knowledge), and it implies interrogating interactions within the shell of social structures which forces the development of ties among individuals (Saqr, Fors, Tedre & Nouri, 2018). In focusing on social presence during online interactions, this construct includes the impact of interpersonal relationships and forces of ties that happen beyond interaction and could perhaps be considered in view of collaborating social structures existing within the learning space. An analytical step into the study of collaboration focuses on cognitive, social, and learning presence and uses Social Network and Message Analysis to review the exchanges of thoughts among students, content, and the instructor. Collaborative learning is amenable collaborative group work (Roberts, 2004, p.208). Conversation and data sharing are used to understand the level of collaboration among students as they log in and out of the Social Network Site (SNS). Individual student participation can be evaluated by determining the number and length of accesses and messages (Hathorn & Ingram, 2002; Roberts, 2004, p.208).

In conversation, the instructor-students and students-students conversations epitomise collaboration in a mobile learning network. According to MacCallum et al. (2017, p.63), mobile tools facilitate instant feedback, communication and collaboration among students and between student and instructor. Many scholars explored how these principles are all underpinned within collaborative learning (Kukulska-Hulme, 2009; Taylor et al., 2006; Traxler, 2007; Zurita & Nussbaum, 2004).

Roberts (2004, p.208) hints at the four typical characteristics of collaboration in a mobile social network that could provide evidence of collaborative learning and these are:

• Shared knowledge between instructor and students.

• The instructor mediates learning activity.

• Shared authority between instructor and students; in this case, the instructor shares the setting of goals within a topic before the students complete the task.

• Heterogeneous groupings of students; this characteristic teaches all students to respect and appreciate the contributions made by all members of the class, no matter the content.

According to McInnerney and Roberts (2009) and Roberts (2004), data sharing is the exchange of information such as text messages, images or videos between the students specifically for learning purposes. This study investigates what kind of learning transpires in such mobile learning. It examines how collaborative activities are accomplished as the learning interest drives them into an engaging end thus producing learning (Roberts, 2004, p.218).

## 1.6 Research Questions

The research question is borne out of my own professional practice and teaching of electrical and electronic engineering to students using suitable technologies in an innovative way. During previous small-scale research investigations, I investigated the issues challenging online engineering education in my country during which I found that mobile learning is pictured at the centre, as a pivotal element of virtual learning. Subsequent investigations into literature directed my research towards mobile learning and I hoped to present a result which may improve mobile engineering education. Before I decided on the nature of the problem and question that would accompany it, I discussed with engineering instructors and students of FUOYE to determine the questions that would be most suitable. In drafting the question, I also considered the existing gap in knowledge and understanding of mobile learning in engineering.

The over-arching question is:

RQ1. How do students studying at a University in Nigeria perceive mobile learning in electrical and electronic engineering education?

And the main research question is sub-divided into these sub-questions:

RQ1.1. When and where do students use mobile technologies for learning activities?

RQ1.2. How do students perceive the authenticity of practices performed through mobile technologies?

RQ1.3. How do students create their own learning by customising activities?

RQ1.4. How do students collaborate on social media for learning purposes?

## 1.7 Ontological and Epistemological Stances in Relation to the Theoretical Framework

I adopt a pragmatist paradigm since the flexibility of the case study allows deciphering reality that is negotiated in the sample space used for study, and reality is understood in the light of how useful it is in the new unpredictable circumstances.

Pragmatism is an educational philosophy that says education's role is to teach students things that encourage them to grow into better people and those are the practical things for life, i.e. constructivism in its practical form (Rai & Lama, 2020, p.1844). Morgan (2014, p.1045) argued that pragmatism can serve as a philosophical paradigm for social research, it does not matter if the research is quantitative, qualitative, or mixed methods based. As a new form, it replaces the older philosophy of knowledge approach which understands social research in terms of ontology, epistemology, and methodology. This claims to be a new paradigm resting on an indication of the wider value of pragmatism as a philosophical system, along with its direct practicality for issues such as research design since the data analytical approach goes through an inductive logical process that demonstrates practical and real ways of constructively improving students' technical competencies.

The point is that we cannot have direct access to reality but must understand it as it is represented through the help of research tools. Socio-cultural theory does not deny the existence of reality rather it argues it is socio-culturally existing, especially in learning. Socio-cultural theory accepts multiple interpretations of an object none of which are objectively valid or true (Polly et al., 2018). Furthermore, the pedagogical challenges facing mobile learning pose apposite questions such as what design principles and frameworks should be used in creating mobile learning environments, and what instructional strategies can best be deployed to enhance student learning (Khaddage et al., 2015, p.627). Understanding the framework of learning in engineering fields and their interrelations in this context leads the quest for knowing learning strategies and structures as their interrelationships are vital.

### 1.8 The Proposed Audience

The main audience are engineering educational developers and educational technologists that are working with or developing learning technologies for engineering education within and outside the university - FUOYE. Beyond the university borders and reach, the audience is other university educational developers in the sub-Saharan region where students share the same educational behaviours or patterns.

Since the high use of mobiles in the Sub-Saharan region has been highlighted in literature, this research may enlighten policy-makers in universities and help to re-purpose the role of mobile devices in educational development. The key audience are the academic staff and researchers who are interested in mobile learning, and technologies in engineering education.

This study informs them of the possibilities in engineering for mobile learning. Most are unaware of alternatives offered by mobile tools to compensate for inadequate learning infrastructure.

## 1.9 The Stakeholders

The main stakeholder for this project is the Federal University, Oye-Ekiti, Nigeria, and particularly the faculty of engineering and finally the department of electrical and electronic engineering. The engineering unit of the University is where the output of this research is most needed. The members of the academic staff and engineering students are directly involved stakeholders.

Another stakeholder is the National University Commission of Nigeria (NUC), a body that supervises and accredits all university academic programmes running in Nigerian universities, and then the National Board for Technical Education, Nigeria, which is in charge of technical education and the provisions for its operation in HEIs.

And, finally, the neighbouring universities in Nigeria that offer the fields of discipline covered and are underpinned in this research context who may deem it helpful to consult FUOYE or the researcher for knowledge and application.

## 1.10 Overview of the Thesis

This thesis covers the following chapters: Chapter One: Introduction and background, Chapter Two: Literature review, Chapter Three: Research design, Chapter Four: Findings, and Chapter Five: Discussion, conclusions, and further work.

# Chapter 2: Literature Review

## 2.1 Overview

This chapter covers four sections: introduction, related works of literature, emerging mobile learning environments in engineering, and summary.

## 2.2 Introduction

The relevance of conducting a review of literature when studying the trends and development in mobile engineering learning is to enable my objective critique of past efforts, identify gaps, and propose new directions for this research (Borrego et al., 2014, p.46). Reviews can reveal gaps in past works or highlight areas where a concept is accepted as true but little evidence exists to support it (Farooq, 2017, p.66 ; Petticrew & Roberts, 2008, pp.1-26). At first, I consulted the literature of an engineering academy advocating for practice in sub-Saharan Africa to understand from the empirical studies in mobile engineering education that: perfect expertise through emerging online learning is missing, and that the expectations of students leaving HEIs is competency in practice developed through learning across multi-platforms. Brown (2003) opined mobile learning as the emerging online learning. In an effort to investigate mobile learning in engineering, Traxler and Kukulska-Hulme (2005) suggest an investigation should be based on current practices and drawn from diverse mobile learning studies. I explored literature in mobile engineering to understand the dimension and direction of previous work so that I could investigate where gaps exist with respect to identified issues mentioned by the engineering academy.

A literature search, from the year 2010 to 20th May 2021, was conducted online with a global-wide search for empirical studies. Selecting 2010 is because it includes a decade when most studies explored mobile learning in the context of this study (Price et al., 2016, p.346). Search phrases placed on the e-library were these; “engineering education mobile learning”, “engineering education mobile applications”, “mobile learning in engineering education”, “mobile learning in engineering”, “m-learning in engineering”, “mobile technologies in engineering education”, “engineering education mobile learning adoption”, and “mlearning in engineering”. A total of 39 papers were gathered and examined bearing in mind the construct of engineering learning – the two intertwined worldviews, the non-abstract (e.g. physical contact with, user interfaced with, doing, or use of tools, etc.) and the abstract (e.g. perception, ideation, thoughts, ideas, knowledge, awareness, or understanding) (Eggink, 2009, p.519; Pothier, 2021). Each paper could include one aspect or both. Many texts outside engineering were also collected in this number and examined since they were either concerned with science or higher education. The inclusion-exclusion yardstick applied was that the selected study must focus on engineering, empirical studies, written between 2010 to 2021, that focused on the context.

I found three fundamental directions and scope of empirical studies. Literature is presented on theory used to investigate this study and on these two themes

– interface and user perceptions, and then emerging mobile learning environments in engineering education are discussed.

Those above appear in detail in the subsequent sections as:

- Pedagogical framework and socio-cultural theory.
- Concept of mobile learning adoption in engineering education based on human/users (i.e. students') perception.
- Concept of mobile learning adoption in engineering education based on interface improvement.
- Emerging mobile learning environments in engineering.

The literature revealed that prior research has varied from the subjectivity of mobile learning adoption in learning engineering to heuristic results of users' interface with diverse mobile tools of learning and includes emerging trends in this aspect of technology-assisted learning. However, the outcomes of users' views and practices have been written with optimism probably because m-learning is yet to be explored fully in engineering education, or many anticipate that it has much to offer engineering education.

### 2.3 Related Works of Literature

Empirical and non-empirical studies, which focus on mobile learning in the engineering discipline have been studied. The literature focuses on mobile learning in engineering, and I looked at m-learning of science by engineering students. I consider the research methods used (qualitative or quantitative) as well as the focus and outcomes of the studies.

### 2.3.1 Pedagogical framework and socio-cultural theory

This project adopts the pedagogical framework for mobile learning, which is a useful framework based on socio-cultural theory, see Figure 1.3. It features nine constructs. According to Sutherland et al. (2009), socio-cultural theory can be traced in so many disciplines and has been developed across micro, meso, and macro approaches to human behaviour with learning technologies. The perspective of socio-cultural theory is grounded on the fact that humans, as learning, reasoning, knowledge, interact with people, are situated in social and cultural practices. Getting involved in these practices serves as a fundamental mechanism for learning, knowing and skill acquisition. It implies that human behaviour, practices, and activities in learning must be a product of history. For instance, a first year-engineering student, with a prior knowledge of colours, adopts that skill in deciphering the capacities of electrical components appearing in colours. The colour arrangement 'ROYGBIV' stands for '*R*ed, *O*range, *Y*ellow, *G*reen, *B*lue, *I*ndigo, *V*iolet', a stylish phrase that represents the hierarchy of seven fundamental colours of resistors, capacitors, and many electronic components and these are the same across all fields of engineering. The colour standard follows suit as BB-ROYGBV-GW, meaning the sequence of Black-0, Brown-1, Red-2, Orange-3, Yellow-4, Green-5, Blue-6, Violet-7, Grey-8, White-9 (Yuden, 2021), see Figure 2.1.

Figure 2.1 A 10Ω ± 5% - Resistor showing colour band for coding.

According to the colour sequence, the first colour on the band is always a ‘Black’ leading with ten to power zero, next is ‘Brown’, with ten to power of one. And the third band is ‘Red’, leads with ten to power of two to become 100, and so on. And that is the colour code standard acceptable in engineering, and by that values of components are expressed (Mitani & Hamamoto, 2010). The above illustration is a simple way of illuminating the socio-cultural influence of engineering learning.  Knowledge is constructed in a continuum as the social and cultural phenomena evolve in the environmental elements - man, artefact, etc. Collaboration appears in the level of interaction or participation of the student with those elements that are factors that predicate how much prior knowledge they have. Interaction, participation, and developing knowledge from the social space are mainstays that pointed to why a suitable framework such as Kearney et al.’s (2012) is adopted, as other theoretical frameworks linked with the use of technology do not feature spatiality and temporality, authenticity, personalisation and collaboration of learning.

An understanding of the socio-cultural perspective of mobile learning can be thoroughly perceived from either learning as a situated activity as illustrated above where learning is mediated by prior knowledge which served as a tool, or as aspects of contrivances - tools, artefacts, and facilities, that mediate knowledge acquisition. Another way to elucidate this theory is by this example. In-university and out-of-university learning simultaneously builds required knowledge. The students use mobile tools in both scenarios. Out-of-university learning may not be intended, and it occurs mainly when they gather in social circles, engineering field trips, networking activities, meet and greet sessions during internships, and so on.

Alternatively, during mobile device use, students do not enter, truly, into the world of engineering and design, but can build some fundamental knowledge and skills that the subject requires as they progress towards engineering design, simulation, and study.

These series of knowledge construction steps, using mobile tools in various forms, are part of the views of cognitive constructivists. According to Martin (2007), cognitivists and constructivists consider humans as autonomous and rational agents that advance their potential by interacting with the environment and components therein, even though it may not be clear that they are related to the environment and artefacts. A tool is thought, diversely, to encompass a wide range of technologies and artefacts (such as scriber, marker, iPad, smartphones), semiotic systems (such as electronic codes, heat and energy charts, graphs), social interactive spaces (such as mobile social networks, online discussion boards), fore-thoughts and experience (such as fundamental skills), and university tools (such as curriculum, academic benchmark specimens, IEEE[4] document verifier) (De Oliveira et al., 2015, pp. 85-88). Interactions with the above appear to raise the need to separate mobile tools according to their level of interactivity as a medium.

A criticism of socio-cultural theory is that since it is rooted in Vygotskian leitmotifs (Vygotsky, 1978), an observational adequacy argues from the perspective that higher order thinking processes are needed for optimal professional practices that are integrally socially-based and it begins at the inter-mental level between and among individuals. This implies that, for professional development to get realised, the teacher should participate in social learning activities. The designer of a learning environment is obliged to identify the needs and goals of students so that the less knowledgeable students can move up through higher stages in the Zone of Proximal Development (ZPD) while supervised by more knowledgeable others which could be the instructor or another student. Mentoring and peer coaching are examples of procedures through which novices could experience knowledge and skill development under a more significant other's supervision (Ameri, 2020, p.1538).

#### 2.3.1.1 Spatiality and temporality of mobile learning in engineering

Depending on the setting, the term 'third place' may have many meanings. Traditional learning assumes the first place of learning, a formal place, and

[4] IEEE stands for Institute of Electrical and Electronic Engineers.

the social environment is the second place of learning where informal learning usually occurs, which can be a field trip, museum, home, library, or other location. Space and time play a role in mobile web-based learning (Cook et al., 2011, pp.187-188). For instance, when a student is out-of-school and indulges in learning that is outside of the curriculum, the acquired knowledge may be extraordinary and may even surpass that taught in the formal environment. The third place is the space that lies between the first and second places where learning occurs (Schuck, 2015; Schuck et al., 2017; Sutherland et al., 2009).

Schuck et al. (2017) viewed the third place as the basis of community and social life and the space in which more creative activity takes place (Oldenburg, 2001). Further, it suggests that it is the social milieu for learning that occurs at the link between the formal and informal settings. It involves the reimagining and recreation of those other spaces to provide an opportunity for creativity, insight, and action (Schuck et al., 2017, p.123). However, one important question is if informal learning exists in the third space or is there a tendency to bring formal learning into the third space since the emerging technologies tend to narrow human or social-cultural activities, moving them from the physical to the virtual world (Schuck et al. 2017, p.129). This leads to asking what can or cannot be achieved in mobile engineering learning, and where does this context situate mobile learning for sound skill acquisition and knowledge development. The engineering students' learning on multi-platforms broadly occurs in conventional online learning environments (using desktops in a fixed location) and mobile learning environments (using mobile devices in non-fixed location).

In content modifications, mobile App developments have successfully deployed from desktop to mobile versions and enabled enhanced mobility of both student and content. The mobile learning space and time or 'spatial' perspective is considered the boundlessness of the art of learning, bringing some highlights and special attention to engineering practice as its major exercises are pragmatic in nature. Its nature invites this study to consider the idea of the space of learning, reality of practice, personalisation of practice and collaboration among users and tools used in practice.

### 2.3.2 Concept of mobile learning in engineering based on perception of users (i.e. students)

The perspectives of engineering learners are useful instruments for constructivism and change. Better designs and steps for improvement are initiated after mobile learning users are consulted and their perceptions analysed. Users' everyday experiences, their perceptions and ability in mobile learning, contribute to understanding the areas where improvement of mobile applications is required (McQuiggan et al., 2015, pp.209-210). It is a need to locate in pieces of literature, findings that student learning and practice reflected real practice, were personalised, and allowed them to interact with other users, devices, and content. The evidence of connection of activities on mobile learning and real practice is describable by the level of engagement and outcomes as shown in Zarei et al. (2018).

It has been established that mobile learning can be internet-based (Kukulska-Hulme et al., 2011) and can be used in offline environments (Shrestha et al., 2010). However, investigated from the essence of pragmatic power, the learning of engineering practice in the milieu of mobile learning environments, becomes a vocation where a student is furnished with expertise and skills but how do the explanations in scholarly works detail how learning can reflect real-practice, be customised, and afford peer-to-peer practice and learning. In an attempt to cover this concern, many scholars have investigated users' perceptions. Ubiquitous wireless network coverage was a background for Huang (2014) and Li et al.'s (2013) examination of users' experience through a mixed method and modified Unified Theory of Acceptance and Use of Technology (UTAUT) model, in a study of mobile learning where ideas that can help achieve virtualisation especially during laboratories and student peer-to-peer networking. Not all engineering topics can be mounted on a wireless network. However, many engineering online practices are interactive and web-enabled, creating multifaceted interfaces to accomplish tasks (Goeser et al., 2011, p.2). In an environment where internet facilities are limited or situations when there is technical failure over the internet transmission, students' practices would be hindered and re-focusing learning and practice by bringing some engineering course, subjects and topics into the offline application's terrain is highly required.  In a development of mobile learning applications for two electrical engineering courses, namely, discrete time signal processing, and digital logic, the Apple iOS and Google Android mobile platforms were compared to elucidate what works for various learning practices. However, such a comparison has become obsolete because of the development of mobile technologies, perhaps, because technology mediating learning is speedily changing every five years (Passey et al., 2016, p.127). Mobile platforms were found to be an evolving technology and mobile applications have become a very crucial part of everyday learning (Potts et al., 2011, p.296). If learning can rely only on web-based tools, it implies that not every student can learn as the internet is not yet everywhere (Bates, 2020). It then requires finding out if engineering learning occurs in non-internet based mobile learning practices that can happen when and where it is suitable.

Furthermore, the implication of mobile learning in engineering under user-friendly interface, content, and personalisation without revealing how student practices reflect real-world engineering tasks is that if interaction outcome is only with the mobile interfaces, other users, and tools used in learning, it will be challenging to understand engineering education from social-cultural grounds, and this was evident in Huang et al. (2015) and Sarsar et al. (2018). There could be acceptance and usability of tools by the students (Poulova & Simonova, 2014), satisfaction with tools (Ahmed et al., 2016; Al-Adwan et al., 2018; Li et al., 2013), shared knowledge (Zarei et al., 2017, p.3), but there is a path showing students' efforts in forming their own learning over the content, such as in the mobile-module version that was used in Sasongko et al. (2017), group knowledge building using the smartphone (Ryokai et al., 2012), acquisition of electric welding skills (Chung et al.,2017), reading (Chakravarthy & Sunitha, 2020), raising motivation (Heo et al., 2018), realising learning purpose (Robert et al., 2015), and support learning (Noum et al., 2019; Sreelakshmi, 2016).

The study by Sasongko et al. (2017) quantitatively examined a single platform of mobile learning. Adoption on a range of platforms could have provided an opportunity for students' personalisation experiences over every engineering specific task. A drawback of studying students' experiences over a single platform is that content delivery is not based on one platform and all platforms are not internet-based (Ogbuju et al., 2012, p.102). Knowing each task's specifics that are accomplishable is a hard-sought answer by educators (Penev et al., 2013, p.186). And this suggests that a student may struggle with the use of mobile technologies to achieve a learning need because of users' lack of experience (Sarsar et al., 2018), or students' attitudes towards mobile learning that are tied to their environment and tools (Munohsamy & Chandran, 2014). Therefore, Huang et al. (2015, p.1088) recommended that future studies examine the connection between adopting m-Learning and actual relevance of it to practice.

In the light of adoption of customised m-learning that reflects real-world practice, Suresh and Hemabala (2013) studied students' personalisation of mobile content and their collaborative activities. The study measured the students' acceptance, level of understanding and usability, but did not capture any exchange of messages and knowledge as evidence of interactive learning at that level, and this is one missing part of that study.  Information about interaction and collaboration is a meaningful way to understand mobile tool adoption in an engineering course (Alshalabi & Elleithy, 2012; May &

Ossenberg, 2015; 2016) as interactivity impacts students' learning (Ebner & Holzinger, 2007). Mobile learning supports learners to develop expertise when they adopt self-regulated learning and collaborative coaching with peers in a mobile-social platform or learning network that resembles a community of practice. Interaction platforms promote high-level learning and transitioning of learning into the real-world experience (Samaka & Ally, 2015).

To have effective learning, m-Learning requires well-tailored forms of user interaction with the mobile device and the creation of content that unlocks the full potential of this method of learning (Penello Temporão & Beltran Pavani, 2020).

Past studies used users' perceptions to explain engineering's mobile learning; however, this was not fully explored, for instance the possibility of students' doing acceptable practice over mobile tools, their competence to create personalised learning through those tools, and interactive activities that socially influence learning. In these past studies, results were derived from students' views that emerged without an environment of interaction with tools and the content of social influence (interactions) was not quantitatively analysed. Understanding mobile engineering education that can enhance problem and project-based learning is incomplete without knowing about the interaction (Lehmann et al., 2008).

### 2.3.3 Concept of mobile learning in engineering based on interface issues and improvements

Measuring learning effectiveness, satisfaction or usability in multi-platform mobile technology used in engineering education cannot be adequate without examining interactions (Moreno & Mayer, 2007), as well as perceptions (Gezgin et al., 2018). Most user perceptions result from concerns arising from interfaces and integration of mobile tool components. Mobile tool integration could create easy or tough settings for students, e.g. interfaces on podcasting devices enable students' abilities because of their offline and asynchronous provision (Palmer & Hall, 2008); however, that was a trial study and did not investigate from the perspective of pedagogy and the integration of customisable mobile interfaces that failed to an extent in supporting students' practices, hinted in May et al. (2016). Interface issues led to major personalisation barriers; this was shown in May et al.'s (2016) customised tool to organise student work and support their scientific inquiry. It shows that barriers facing learning in personalising content exist and based on that empirical study that merging personalised and educational contents cannot be supported.

The mobile tool's interface is the location or environment where the user communicates or interacts with a mobile tool (Sharples, 2000, p.186). Understanding where engineering tasks can happen, on which interface and platform, has not been studied. Many studies examined mobile learning in terms of the complexities of the interface and technical factors that shape learning. The interface type where students perform learning is crucial because it determines the outcome of practice and experiments (Lai et al., 2007).

Some mobile engineering learning activities have been conducted in the internet-based environment and such empirical evidences did not provide explanations of which tasks and practices can be done with the internet, or not, to tell how the students acquire skills in each practice and task (Huang, 2014; Li et al., 2013). For instance, mobile learning was claimed as most fit for higher learning because of its ubiquitous wireless network coverage (Li et al. 2013, p.474). However, it does not completely fit a debilitated learning setting (Kehinde et al., 2012). This implies that understanding the aspects of engineering practice that fit each part is necessary.

It may be helpful to know if the interactivity that promotes learning occurs in non-internet, internet-based mobile environments, or both. The interactivity among users, content and devices and the forces inducing it in the learning environment, even though it considered social behaviour as a construct, will help in explaining how an engineering task will be appropriated to which tool and its version that is needed to run the task. For instance, the significant predictor of acceptance of the smartphone as a learning tool is learning through a video (Suresh & Hemabala, 2013). The media interface determines the students' behaviours and habits (Schuster, 2014; Schuster et al., 2016), because students' understanding of usage and mobile learning habits are related (Schuster, 2014); this was demonstrated in a simulation exercise via a remote laboratory by Jiang et al. (2018), where it showed that students' readiness of mobile learning adoption and their mobile learning content count on the students' self-efficacy.

There exist interface drawbacks; however, research for techniques for evading or managing these drawbacks is needed (Criollo-C et al., 2018, p.5).

Several scholars considered interface to be vital in mobile learning evaluation practices that students have accomplished on interfaces and highlights include: the analytical role but with minor functionality errors (Purasinghe & Alam, 2006), scientific inquiry skills (Cheng et al.,2016), multi-device integration that offered multimedia for digital library (Davcev et al., 2007), cloud-based designing (Chang et al., 2017), practicing with Mobile Apps (Jou et al., 2016), an engineering course via Moodle LMS depicted weak connectivity (Al-Zoubi et al.,2010), multi services involving SMS (Coşkun & Demirturk, 2016), interactive web-based courseware (Goebel et al., 2016), a multi-agent approach that offers collaborative learning (De La Iglesia et al., 2015), a complementary tool for embedded system learning (Ma et al., 2016), sorting algorithms that fit only smartphone and tablet (Meolic & Dogŝa, 2014), electronic measurement and modelling, suitable for mixed reality settings (Mesáros et al., 2016), improved control using sliding mode control and proportional-integral-derivative (PID) (Demirtas et al., 2013), using a virtual electric manual to support practice (Luis, 2016), mobile data protection and genuineness (Mallya & Srinivasan, 2019), personalised engineering graphics (Jovanović, 2017), and mobile LMS (Istanbullu, 2008). It is noteworthy that learning is not evaluted in the above mentioned interplays between student and tool.

Implementing the engineering tasks shows benefits and drawbacks; however, drawbacks arising from difficulty to personalise tools and learning are paramount as it contributes to attaining the required standard of practice. So, to avert that difficulty, usage and familiarisation become the mainstay for every student (Simonova et al., 2015). Hence, familiarisation is needed with each mobile interface to know where a task or practice can be undertaken. However, there is a lack of research that focuses on user familiarisation without explaining mobile learning in the context of authenticity (Kearney et al., 2019, p.759; Sung et al., 2016, p.263). Students become familiar with what they see and do.

Virtualisation is a property of mobile tools, especially in virtual worlds; also it has been emerging in mobile tools in engineering, and it did not appear without drawbacks in control, so, understanding how to improve it is necessary. In troubleshooting with Virtual Reality (VR), interacting with a three-dimensional model is possible (Singh et al., 2021); however, the control mechanism has been a concern even though VR has had a significant positive impact on student knowledge, learning motivation, and cognition. In situations where VR prototypes were simulated in mobile interfaces, it was an individualised practice, meaning that it has not widely come into play in collaborative tasks (Valdez et al., 2017).

In some areas, Augmented Reality (AR) is integrated into m-learning, as AR aims to improve visualisation (Alfred et al., 2010). However, visualisation aids personalisation by improving the content delivery. For instance, it can be used to develop teaching materials (Dorado et al., 2016). Bringing mobile learning through an expensive tool such as AR may or may not favour higher education in every learning environment. Virtual world mobile tools are notably expensive to some students (Bell & Fogler, 1995, p.1719) except those achieved by integration (Román-Ibáñez et al., 2018), and hence achieving visualisation of objects may be sought in tools that are not virtual worlds through adaptivity and flexibility of the mobile tool's adoption. Adaptivity and flexibility are essential as well as standardisation of content (Al-Zoubi et al., 2010), because they make mobile learning become an accepted mode for the next generation (Lai & Liou, 2007). Students are attracted to interactive and pliable mobile features (Kramer & Strohlein, 2006). This underpins the need for research on flexibility and adaptive content that can be exploited on mobile tools.

Some interfaces communicate through internet connectivity and so, connectivity issues may hinder practice and learning. Finding solutions to engineering education via mobile tools in the absence or presence of poor connectivity is necessary because it is possible to find specific engineering programs, task, courses, and practices that can be used in a non-internet supported mobile platform (Al-Zoubi et al., 2010).

Furthermore, all these studies have only either studied the learners' perspectives, instructors' perspectives, or both without going deeper into the interactivity that influenced learning. By including social media in mobile learning, additional engagement, interaction and collaboration among students, in a self-directed learning environment, is maintained (Chakravarthy & Sunitha, 2020, p. 2438). That made sense for the purposes of the mobile social space that has today created a demand for research as dominant modes of online learning are failing to engage learners despite the attractive potential of the digital environment for learning (Hemmi et al., 2009).

A good number of students show a strong tendency towards technology-based, student-centred learning. This is another area where mobile learning has broadened learning horizons (De La Iglesia et al., 2015; Herrera et al., 2015). Students are partial to social interactions, more so when there is mobility. Lytras et al. (2014) confirmed the result of scientific research on technology-enhanced learning in the context of mobile social networks. They summarised that the main pillars for future scientific learning contributions are enabling technologies, and Next Generation Social Networks. There are new possibilities that digital technologies can offer in technology-enhanced assessment from the mobile social context (Chigne et al., 2016).

To address problems facing engineering education where laboratory work is essential, Huertas et al. (2020) studied the current capabilities of cellphones, software, and social networks in offering a laboratory activity at a low cost. It used a quantitative approach and investigated the learning impact. One thing missing is that core courses in engineering have not been examined.

Presently, in developing countries, the predominant aspect of mobile learning in engineering education is mobile social technology-enhanced learning (Rhema & Sztendur, 2013). Students have advanced several learning behaviours and skills by identifying with various online groups where they learn collaboratively either in an asynchronous or synchronous mode.

With the presence of mobile social artefacts, successful m-learning experiences can be helped by mobile learning environments that are multi-facetted and effective, and that meet students' needs (Astatke et al., 2015; Attwell, 2007; Harpur & de Villiers, 2015; Johnson et al., 2008; May et al., 2015; Samaka et al., 2015). Leveraging mobile tools for higher learning in general, and engineering education in particular, is a pressing concern for engineering educators (Khan & Chiang, 2014).

Those scholars' works focused on interface improvement in the non-spatial perspective but time and space as well as interactivity are highly relevant in defining mobile learning (Kearney et al., 2019, p. 753).

Emerging mobile technology has come with new possibilities, Penev et al. (2013) compared factors such as internet, mobile devices, and social networks (Criollo-C et al., 2021, p. 2), that require adaptation of the learning methodology and control of the knowledge according to the new possibilities. In their study, the practical possibilities included modern smartphones, phablets, tablets, multi-touch screen, accelerators, navigation, and geo-positioning tools. An analysis of the key elements of the educational process is accomplished, oriented towards engineering subjects, for example algorithms, schemas, tables, and processes. The possibilities of modern mobile devices for organising and carrying out educational processes in the field of engineering education are highlighted from a functional and methodological point of view. It follows that there is no definite platform that is a focus, and engineering tasks were not specifically defined with respect to tools.

Before the introduction of m-learning in engineering, Lipovszki and Molnar (2007) investigated m-learning from the technological point of view. Their study's basic concepts and technological considerations are, today, prioritised as they led the way in mobile learning investigations. Their study sought to address issues such as the hardware, software, and network solutions, and considered the technology as its main research focus and did not investigate the users' perspectives and connections with pedagogy.

In conclusion, the literature discussed above mainly used quantitative methods and considered both goals, i.e., the interface and technological complications of mobile learning, in the overall evaluation of success of mobile learning in engineering. However, understanding where specific engineering tasks can be accommodated and practiced by students is yet to be known, and generic approaches that students can adopt to evade these interface and technological drawbacks, or improve their learning journey are not yet established.

## 2.4 Emerging Mobile Learning Environments in Engineering

Mobile learning started to make its presence in engineering within the last decade, and its development is still in progress (Punithavathi & Geetha, 2020, p.785). A modern smart education will constitute smart learning systems – technology, pedagogy, and students.  A smart learning system is a student-centred approach (Middleton, 2015, pp.15-20; Punithavathi & Geetha, 2020, p. 789). However, smart mobile technology is evolving as well as pedagogy, but a student focus comes from understanding all the features and concerns of student learning and practice and providing them with the required environments.

Emerging pedagogies for engineering education expects these 4 essential features (Punithavathi & Geetha, 2020, p.786):

1. Authentic, situated, and contextual: analysing engineering students' ability to apply their knowledge and skills to evolving problems that require solutions, in the real-world and in line with their subjects (Bosman & Fernhaber, 2017). The changing nature of human problems demands an education system that can analyse current engineering issues and proffer solutions (Brown, 2009). A smart engineering educational pathway matches that. And knowing the deficiencies of an engineering education in certain group of students becomes essential. Learning analytics can reveal the concerns of the next generation and learning challenges, and the targets for a new field of learning. Real-time results from analyses are used by students, instructors, and academic advisors to advance student success (Elias, 2011, p.4). As situatedness and authenticity of engineering learning are important, it follows that investigating this, through a sound analysis of learning, is also helpful. Only a few studies have sought to provide a comprehensive repertoire or response to how real-world problems are perceived by engineering undergraduate students.

2. Customised and personalised: Student-centred learning is assisted by personalisation of mobile learning technologies (Hwang, 2014). For instance, personalisation as a result of sensing technologies, such as GPS (Global Positioning System), RFID (Radio-Frequency Identification) and QR (Quick Response) codes, which have further enabled learning systems to detect the

real-world locations and contexts of learners (Hwang et al., 2008). Also, location awareness in mobile learning can be supported by many other technologies, such as accelerometer, or gyroscope (Ali et al., 2014, p.26). In this context, analysis of personalisation has been accomplished by a good number of scholars and many agreed that mobile systems can provide not only learning activities relevant to the learning objectives in the students' environments, but also permit students to hand-pick their preferred tasks to execute (Kinshuk et al., 2009). The question becomes, how general is this personalisation in engineering practices?

3. Collaborative, highly social, and dynamic interactions: interdependence, interaction, individual accountability, exchange of data, and progress monitoring are features of collaboration (Kim et al., 2013). Engineers do not work in isolation. Interaction plays an important role in engineering education as preparation for engineering practice (Khan & Chiang, 2014, p. 1077). As highly complex engineering projects cannot be conceived and created by an engineer working alone, collaborative learning is essential in preparing engineering students for the challenges of the future (Göl & Nafalski, 2007, p.175). Emerging learning environments become interactive and dynamic settings that use modern technology to advance knowledge and skill development (Junfeng, 2012). Finding the technology drivers and delivery technologies for futuristic mobile learning is recommended (Punithavathi & Geetha, 2020, p.786).

4. Learner-centred and responsively adaptive: for effective teaching and learning in higher education, the shift has gone from teacher-centric to

student-centric pedagogy, but it is equally challenged by student-oriented factors (Catalano & Catalano, 1997, p.5). Learner-centredness is a constructive dynamic system that permits the student to adapt, as the student interacts and learns in the vicinity surrounding the student. Adaptability involves self-regulated practice which includes the student setting learning targets, self-observation, self-assessment, and self-reinforcement. This is because hurdles of metacognition-thinking of searching the unknown, are believed to have a great influence on learning outcomes and student performance (Schreurs & Dumbraveanu, 2014). Engineering skills are built upon prior skills and knowledge; however, innovations over a range of emerging technologies pose hurdles to learners and this is where adaptability helps. More so, the progress of technology facilitates students' lives by building smart and personalised solutions with respect to their personal and academic profiles as well as their real environments. This is because mobile technologies have the capacity to detect the contextual dimensions of learners through different sensors (Ennouamani et al., 2019, pp.16-18). So, whether student-oriented resistance to learner-centrism exists or modern technology can ease the challenge students face of adaptability when practising and learning engineering activity, this thesis aims to identify where it stands between these two sides.

### 2.4.1 Concerns

Most empirical literature investigated had successfully studied the users' perceptions of adoption of mobile learning, and the interfaces' technical complexities; however, none considered investigating these two across multi-platforms of online learning. Mobile learning has a window of opportunity in engineering education in four predominant online streams. Four major areas have been identified by literature for hosting future learning: the virtual public space (YouTube, Facebook, etc.), the LMS, the Toolbox, and mobile applications (Broadbent & McCann, 2016). Presently, the emerging mobile MOOC, e.g., MobiMOOC, has potential for teaching increasingly high numbers of students entirely online and for revolutionising the higher education landscape (DeWaard et al., 2011). However, learning engagement must be augmented to utilise the huge potential offered by mobile learning. There is a need to motivate students to actively participate in online courses and to interact with instructors and fellow students using social and technical networks (Heckel et al., 2016).

There could be an observable gap when mobile learning is run in an active learning environment, such as problem-based learning; it is understandable and acceptable as m-learning environments tolerate all kinds of learning (Vavoula et al., 2009). However, group or self-learning and transferability skills obtained by students during mobile learning override that assumption of gap. For instance, there is positive synergy between problem-solving and mobile devices as mobile learning eases the learning challenges for engineering students. And it is evident in the learning settings. Luis et al. (2015, p.6) stated that, irrespective of the infrastructure aspects and the fore-knowledge or experience needed for working with mobile devices, problem solving can be handled by mobile engineering education in the four aspects of mobile learning previously mentioned by the Academy of Engineering. Mobile learning found its way into higher education engineering programmes, to aid in filling the learning and skills demonstration gap. Chang et al. (2017, p.109) recommended further research into other appropriate applications that can assist in guiding students.

Most research into m-learning adoption in electrical, electronic and other engineering disciplines has focused on solving the interface and media issues that constitute major drawbacks of m-learning (Al-Zoubi et al., 2010; Coşkun & Demirturk, 2016; De La Iglesia et al., 2015; Demirtas et al., 2013; Dorado et al., 2016; Goebel et al., 2016; Istanbullu, 2008; Lipovszki & Molnar, 2007; Luis, 2016; Ma et al., 2016; Mallya & Srinivasan, 2019; May et al., 2016; Meolic & Dogŝa, 2014; Mesáros et al., 2016; Palmer & Hall, 2008; Penev et al., 2013; Simonova et al., 2015). While these studies have concentrated on amending interface challenges so that m-learning is easily adopted in engineering, little is mentioned of how interface issues affect learning or its influence on learning and how learning can be managed. Investigating the actual learning that occurs in m-learning is invariably useful as it aids curriculum development (Vate-U-Lan, 2008).

The usage of different kinds of mobile tools constitutes the teaching and learning processes in engineering education. Learning content has been packaged in various platforms that require different interactions, approaches, and skills, and that has left mobile learning users with distinct perceptions. Perceptions and interactions are helpful to determine the usefulness, satisfaction, and usability dimensions of m-learning (Sharples, 2009).

Many scholars have measured perceptions using various models (Ahmed et al., 2016; Al-Adwan et al., 2018; Chakravarthy & Sunitha, 2020; Huang, 2014; Li et al., 2013; Poulova & Simonova, 2014; Sarsar et al., 2018; Sasongko et al., 2017; Zarei et al., 2017; Zarei et al., 2018). These studies evaluated usability, effectiveness or satisfaction based on perceptions without in-depth examination of interactions; some focused on students only, while others focused on students and instructors. However, perceptions across general platforms used in engineering were not evident.

In other studies, perceptions and interactions in the learning setting were evaluated (Chang et al., 2017; Cheng et al., 2016; Chung et al., 2017; Davcev et al., 2007; Heo et al., 2018; Jiang et al., 2018; May & Ossenberg, 2015; 2016; Robert et al., 2015; Schuster, 2014; Schuster et al., 2016; Suresh & Hemabala, 2013). These studies adopted diverse backdrops of engineering, even though multi-platforms were not used. There is a huge opportunity for knowledge building through interaction and collaboration using many virtual platforms (Pearce et al., 2012). However, the general understanding of effectiveness, and appropriation of m-learning in engineering to create meaningful learning is required across the four extensive virtual platforms: Learning Management Systems, mobile Apps, social or public spaces, and virtual toolboxes such as Workshed[5] (Broadbent & McCann, 2016). Mobile-based solutions can be helpful to support learning, especially where there is a

[5] https://expeditionworkshed.org/materials/

lack of hi-tech laboratories as is the case in many Nigerian institutions (Grimus & Ebner, 2013, p.2028).

Engineering education cannot provide all the training a student needs using a single virtual platform (Mlitwa & Wanyonyi, 2015). So, this study explores learning across multiple virtual locations, providing wider insight as is required in engineering m-learning.

Students acquire and demonstrate skills using mobile tools through an interactive process of individual hands-on and group participatory learning. The relevance of interaction in engineering learning, and the study of effectiveness or usability may not be adequate without studying the unseen activities in the mobile learning environment and whether learning is authentic, customised, and collaboratively achieved (Kearney et al., 2012). This range is to explore the relationship between the perceptions of m-learning and the actual behaviour in practice. Behaviours are expressed by how, where and when the students personalise learning, balance skills with real practice, and learn collaboratively.

Furthermore, all these studies have only either studied the students' perspectives, the instructors' perspectives, or both without deepening into the interaction behaviour that influenced learning. Also, each used one out of those four platforms of engineering education in their study, i.e., LMS, social media, mobile apps, and toolbox. In this study, the perspectives of participants based on four platforms are investigated in addition to looking into learning analysis of interactions on at least one of the platforms – the social space.

### 2.4.2 Questions

There are worries - that mobile learning is surrounded with concerns covering learning with mobile devices, environmental issues, device complications, and users' concerns. For that, a prior study, carried out by Astatke et al. (2015) in the same setting, recommended that more research should be carried out regarding mobile learning to provide in-depth information to academics and non-academics, so they can provide quality education to students. Also, since mobile learning is advancing quickly and likely to be an efficient way of delivering higher education instruction in the future, it is necessary to look into ways to adapt the device easily for learning and other curricula activities (Shonola et al., 2016, p.49).

Encounters with hindrances that challenge learning give rise to perceptions and interactions. Concerns about these hindrances to learning such as those emanating from technical and interface drawbacks, diversity of engineering practices, and disruptiveness of mobile technology and mobile social tools, have raised questions for this study.

Engineering education is facing promising developments in the area of learning with mobile tools and this is where personalisation and preferences are taken into account, adding interactions between a mobile tool (of the user) and the real-world (Madeira, 2010), e.g. asking a mobile App to provide resistance value of a resistor when the colours, represented by numbers on the keypad, are inserted. And engineering education is constantly challenged to bridge the gap between classroom and real-world problems (Alqudah & Al-Qaralleh, 2012). A gap comes from the challenge of accessing developmentally appropriate problem-based and self-directed mobile learning tools (Alqudah & Al-Qaralleh, 2012, p.32). Convenience in this context means as much as possible that the mobile device can be usable in engineering education despite drawbacks.

Mobile learning devices offer both downsides and advantages (Odukoya et al., 2017). Drawbacks and benefits of use of mobile devices in learning engineering have been over-lapping. For instance, some claim mobile devices are not suitable for engineering learning because of their short battery life while others contradicted this.

Mobile learning tools are devices and software that are used to harness mobile learning (Crompton & Burke, 2018, p.53; Ferdousi & Bari, 2015, p.308; Krull & Duart, 2017; Sharples & Pea, 2014, p.234). According to Chu et al. (2010), beyond using special applications, such as MindTool[6] to support learning, one major problem of mobile devices is the lack of suitable layout that can guide the students in learning in a complex scenario. Students might feel excited when using mobile devices for learning; however, their learning achievements could be disappointing when they cannot be fully supported (Chu et al., 2010). This is buttressed by Poulova and Simonova (2014) who

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[6] Mind Tools for learning https://www.mindtools.com/

stated that the weakness of mobile technologies is appropriating design of teaching materials that can suit the smaller display of portable devices. In previous research, awareness of the constraints of the user interface is essential. For a long time, in the engineering design process, mobile devices were disapproved of because of their small screens, poor input methods and limited battery life. Therefore, the interface design and its integration in engineering learning must meet users' needs without overloading them with unnecessary complications or operating too slowly (Parsons et al., 2006). Parsons et al. (2006) contended that planning of mobile learning for engineering is not as easy as it may look because tool design must suit the user's profile and the content.

Löwgren and Stolterman (2007) classified mobile learning application profiles and content into core, periphery, and context. The core group are the students, periphery refers to those not actively involved in social streams such as instructors, and the context is the society that the user belongs to, and the context implicitly influences the mobile learning students such as parents and HEI. This trio portrays the complexity of mobile device application integration in engineering and postulates why respectable and generic mobile integration is essential (Löwgren & Stolterman, 2007). Furthermore, Mota et al. (2018) supported Löwgren et al. (2007), in expressing the complexity of mounting learning in engineering solely using mobile tools, using an illustration of the design and deployment of an augmented reality mobile application. The complexity associated with design and development of components is in training users how to use them (Mota et al., 2018). In another scenario, integrating tools are expensive, for instance, portable microcontroller applications are not easily affordable, and this cost poses additional drawbacks to adopting integrated mobile technology in learning (Riojas et al., 2012, p.29). However, from the perspective of computer engineering, mobile tools are becoming more capable of supporting communication services and handling learning content. The use of mobile technology in learning can solve some traditional learning difficulties facing learners and that the instructor needs to find a suitable system that can facilitate and enhance the learning process (Sarrab, 2015).

In an example of accessing mobile tools for learning in bioresources engineering, an application of simple electronics, LabView[7] that was employed in the field for an agrarian task, was shown to have a high level of efficiency and effectiveness of power utilisation which posits that a decent energy saving ability to function ratio of mobile devices is attainable (Bietresato et al., 2019). In terms of energy saving ability, the ideas and experiences of mobile device users in bioresources engineering contrasts that of biomedical engineering students (Bietresato et al., 2019). Similarly, from process design engineering, Parsons et al.'s (2006) view is that mobile learning system design should focus on creating a system that suits the users' choice and profile. However, Parsons et al.'s (2006) view contrasts with the

[7] LabView; https://www.electronics-notes.com/articles/test-methods/labview/what-is-labview.php

views of others, such as in: the device’s part (Bietresato et al., 2019), integration complexity (Kinshuk et al., 2011; Mota et al.,2018), user’s ability (Huang, 2014; Troussas et al., 2020), and interface (Ali et al., 2014; Ma et al., 2016; May et al. 2016), which suggests that there has not been a single direction to which more attention should be given when creating a mobile learning system plan for students.

The most promising feature of mobile tools in learning contexts is its provision of perpetual connection among users; it has been shown to facilitate collaborative fieldwork activities (Rogers et al., 2004). In the automation engineering laboratory, Frank and Kapila (2017) showed that students connected in a portable Mixed Reality Learning Environment (MRLE), installed on multi-touch mobile devices, demonstrated improvement in their knowledge of dynamic systems and control ideas and acquired positive experiences using the platform. The drawback of the MRLE is that the approach requires students to stay close to the equipment, imposing restrictions on complete access that reduces the extent of its mobility. The provision of a perpetual connection among students during laboratory practice has made the use of mobile devices appropriate for collaborative learning and qualitative evidence of self-adaptation indicated benefits for mobile learning (De La Iglesia et al., 2015; Herrera et al., 2015).

Various engineering fields have overlapping views about the drawbacks and advantages of mobile learning, and it obscures understanding of how it is possible to align mobile learning in engineering when there are various fields, e.g. automation, power systems, computer, mechatronic, and electronic

(Riojas et al., 2012). Perceptions arising from real-world practice and personalisation of practice have been ascertained from students that did tasks in these various fields. Understanding what engineering concepts that are explained by perceptions and interactive experiences of using mobile applications and the usefulness of each tool to student practice regardless of the specific engineering discipline becomes necessary. Some studies have tackled similar questions with the intention and resolution to teach concepts that are useful across a wide range of engineering disciplines (Custer et al., 2010; Merrill et al., 2008; Riojas et al., 2012).

Several factors have been pushing students to adopt mobile devices for reasons which are termed as situational effects exhibited when users select from the offered mobile applications in engineering education (Osborne, 2014). According to Osborne et al. (2013), mobile affordances can be understood by acknowledging what mobile technology offers in supporting learning, describing affordances as how mobile tools aid learning. Osborne et al. (2013) also highlighted “Bring Your Own Device (BYOD)”, a cultural paradigm of today that translates as the use of mobile tools to enhance learning in universities with the device the the learner deems most suitable (p.3). Engineering students use various types of mobile device following the BYOD principle (Afreen, 2014).

Diverse interpretations of scholars who have worked on mobile learning in engineering may have strengthened Kukulska-Hulme's (2009) contention that there is no clear definition of how mobile tools may be used to meet learning needs. Does this hold for engineering education? And if yes, how well does it fit in electrical and electronic fields of engineering? Kukulska-Hulme (2009) explains further that it all depends on how the student's educational purpose attracted a specific choice of tool. This open statement may have drawn engineering mobile learning users into confusion, declaring drawbacks as less important than the potentials of mobile tools or BYOD over the potential of a required mobile tool for a specific task.

The volatile modes of interactive learning provided by mobile technologies may not be comfortable within the higher education engineering context because of lapses associated with the artefacts used and the distractions from mobile social environments (Hemmi et al., 2009). Mobile technologies continue to encourage scholars to engage with modern research directions such as attempting to address the following. Finding the extent to which the modern mobile social applications challenge understanding of the way in which knowledge is generated, disseminated, and assimilated among learners. Do learners appearing on mobile social spaces possess the kind of 'technoliteracy' (Kahn & Kellner, 2005) that will enable them to handle and create academic knowledge within 'disruptive' mobile social settings as some scholars claim that social technologies are prone to being a distraction (Hemmi et al., 2009, p.29). Researchers have also been concerned at what kind of learning would work best in such spaces considering that a drift from e-learning to mobile learning to mobile social technologies is evident and growing among students (Hemmi et al., 2009). Furthermore, distraction has been criticised as a hindrance to adoption of mobile learning and mobile social learning, even though users shape how to adopt technologies for learning (Kaliisa & Picard, 2017, p.2). Are there ways through which engineering learning can thrive amidst the long list of criticisms and drawbacks that have been claimed? If these major drawbacks can be handled effectively, sound engineering learning may be possible.

### 2.4.3 Methodological approaches taken by previous studies and their pitfalls

The methodological approaches adopted by previous studies to investigate mobile learning in engineering include mixed methods, qualitative, and quantitative approaches. However, the essence of engineering education is to impact real-world issues by offering solutions using knowledge and skills. In that vein, Kearney et al.'s (2012) model is appropriate to explain knowledge in the real-world scenarios of engineering using its constructs of authenticity, personalisation and collaboration. Moreover, collaboration can be analysed using a qualitative or quantitative approach since interaction is embedded in collaborative learning. All of the previous studies lack explanation of the trends and behaviour that occur during learning - transfer of an idea from a source to a destination, as well as perceptions of mobile learning users. These are areas that will be addressed in this thesis.

## 2.5 Summary

In examining the perceptions of students that use mobile learning or various factors that contribute to the establishment of mobile learning platforms, Huang et al. (2015, p.1088) recommended that future studies should examine the linkage between students' intention to use m-learning and actual usage when m-learning applications have been implemented. Chee et al. (2017) recommend research should pay more attention to the gap that is a scarcity of research and development of m-learning to synthesise knowledge in the m-Learning field. However, Broadbent and McCann (2016) suggest that the gap is that acquiring general perspectives of effectiveness, satisfaction and usability of m-learning in engineering, across the diverse virtual platforms in relation to real-world applications, have been lacking. Broadbent and McCann recommend finding out the challenges of learning tools, and how better learning can take place on these multi-platforms. Aranburu et al. (2019) advise that finding out how to improve learning comes through investing in the user's views, and an understanding of what occurs when students use those tools to learn. That is why this research becomes necessary to reveal what works and what does not work in engineering's mobile learning. The mobile learning pedagogical framework developed by Kearney et al. (2012) is selected for this study. And it becomes a lens through which to view the research questions, "How do students studying at a University in Nigeria perceive mobile learning in electrical and electronic engineering education?" Each of the 4 sub-questions has been set out to explore knowledge through the constructs of the mobile learning pedagogical framework (Kearney et al., 2012), and the reason is that this research is pivoted on the mainstays that interconnect a learner and tool which are social, cultural, and technological (Sharples, 2000, p. 186). The sub-questions and the constructs they relate to are as follows: 'When and where do students use mobile technologies for learning activities?', 'How do students perceive the authenticity of practices performed through mobile technologies?' (authenticity), 'How do students create their own learning by customising activities?’ (personalisation), and ‘How do students collaborate on social media for learning purposes?’ (collaboration).

# Chapter 3: Research Design

## 3.1 Overview

This chapter covers methodology, research method, selection of participants, researching as an insider, data collection and analysis, ethical consideration, and summary. This chapter describes my research design and how it contributes to this study. And it explains the rationale behind using mixed methods for this research and the method I adopted. There is information about the participants, how they were recruited, how the data were collected and analytical process of those data with the premise of ethical consideration and procedures. I recognise my position as an insider researcher and the bias on the interpretation of my findings, and the chapter is wrapped up with a summary.

## 3.2 Introduction

The methodology of this research was chosen based on the research context, the aim of this research, and research questions together with the research paradigm. I adopted a pragmatist approach with a constructivist perspective in investigating the mobile learning in FUOYE as a case study.  The case study research strategy of this study will be based on a concurrent mixed methods approach, a combination of quantitative and qualitative research methods at the same time. My intention was to capture the experience of students in mobile learning use in engineering learning. And I have this as my overarching research question, ‘How do students studying at a University in Nigeria perceive mobile learning in engineering education?’

### 3.3 Methodology

Finding about the factors influencing mobile learning and analysing its use in learning are subjective and objective, this is because two facets of examination of tools used for learning that contribute in furtherance of new ways of adoption and design are on interaction analysis (Sung et al., 2016, p.254), and views or experiences of users (Aranburu et al., 2019). And for that, social scientific research considers the subjectivity, people’s views, as well as objectivity for finding human behaviour over use of technology. It finds observable human behaviours superficially that are explainable and hidden behaviours that are deeply rooted and only explainable by logical reasoning and mathematical proofs - by extension qualitative and quantitative approaches. This means using a qualitative approach to know the practical effect of their learning tools and the quantitative approach to understand the extent of that practical effect. This research could have investigated only the perspectives of the mobile learning students (i.e. subjectively), but I believe research that involves mobile technology in the practice of learning must examine the interactions that exist in mobile networks since mobiles are all about ubiquitous connections among users who engage in learning (Sampson et al., 2013). Social structures are not explainable only through subjectivity as individuals influences their large networks of people, and vice-versa (Barresi & Juckes, 1993). Connections in these networks and traces of communication are not visible. Mobile learning users cannot explain everything that is involved beyond their experiences such as interactions in a collaborative learning process.

### 3.4 Pragmatism

Learning influences created by mobilities and connection of users at various locations and the users' perceptions are explainable through objectivist and subjectivist perspectives respectively. Pragmatism implicitly permits both subjectivity and objectivity in the light of post-positivism and constructivism (Creswell, 2013). The four research questions are connected to both subjective and objective solutions, and I considered a paradigm that suits those research questions and that is directly connected to practice, i.e. students doing engineering learning through practice. Therefore, pragmatism is selected for this study because it undertakes a step that imbibes positivity and a constructivist's view to explain human experience and hidden influences on learning across mobilities - device, content, user mobilities. The worldview of mobile learning in engineering for a university may be different for being a university situated in an educationally debilitated setting. Worldview is synonymous with pragmatism (Creswell & Plano-Clark, 2011); it is a way of thinking about and making sense of the complexities of the real-world (Patton, 2002, p.69).

If this study must explain perceptions of mobile learning in engineering, it must understand the real-world interpretations of mobile learning engineering students and suggest how to improve adoption in learning. Pragmatism is situated in a paradigm that uses inquiry to find new practical ways of doing things (Kaushik & Walsh, 2019, p.6). Also, pragmatism is selected for it typically supports quantitative and qualitative approaches; pragmatism embraces the two alternatives and offers a flexible approach to research design (Feilzer, 2010; Morgan, 2007).

### 3.4.1 Mixed methods

Creswell and Plano-Clark (2011) state that this approach can be achieved by doing quantitative and qualitative data independently or simultaneously. Before I took the step to investigate the FUOYE as a case study, I considered an approach appropriate that could deliver most detailed results. I selected a mixed method because of the need for clarity of participants' views and inquiring about the activities within the mechanism of learning which a quantitative method can do better. There are activities that only quantitative measures can provide answers to (Hove & Anda, 2005). The concurrent mixed method permits both qualitative and quantitative approaches to supplement meaning to each other while both can start simultaneously. This is best fit for this study since the quantitative segment neither depends on the qualitative segment nor its outcomes, rather it adds more knowledge to qualitative results. An alternative approach I could have taken was a concurrent triangulation mixed approach, which requires doing both approaches at the same time and in equal measure. However, the research questions are targeted to address issues which do not have equal treatments, looking through the lens of the Kearney et al.'s (2012) model. Considering the sequential mixed approaches such as the sequential explanatory, sequential exploratory or the sequential transformative mixed method, none were suitable as all of them require that one method leads to the other and the methods must be dependently analysed. The sequential explanatory approach envisages that a quantitative approach precedes the qualitative one while in the sequential exploratory, it is the reverse (Creswell et al., 2003). Looking on those major constructs of Kearney et al.'s (2012) framework (see Section 1.5.4), all can be answered by qualitative data due to each individual's subjective position. However, it is better for collaboration to gather quantitative data since network structures, connectivity, and interaction are evident in mobile social environments (Gomez et al., 2016), and they can be deduced. Qualitative methods dominate the study because research questions one, two and three are answered by interview questions only, while the fourth is answered by quantitative data analysis alone.

### 3.4.2 Case study approach

The case study is correctly understood as a particular way of defining a case, not a way of analysing it (Gerring, 2004). Stake (1995) and Yin (1981; 2013) conclude that case study is in essence a convenient label that can be applied to any social research project (Tight, 2010). It is not a methodology but often selected for what is to be investigated and for its interest (Stake, 1995). There is no sample that signifies a larger population, and sample size is usually small (Denzin & Lincoln, 2008; Ridder, 2017). This study adopts a single case investigation. Potential benefits of a single case study are found in the description and analysis that offer deep understanding of "how" and "why" things occur (Ridder, 2017, pp.2-7). Many scholars have provided various descriptions of case study. Yin (2006) described it as a method, and it has also been described as a strategy (Grösser, 2013), as a tool (Bassey, 1999), and as a methodology (Noor, 2008).

Case study permits in-depth investigation of unclear or emerging phenomena and at the same time holding onto the meaningful and holistic characteristics of the real-world. In other words, the all-inclusive feature of a case study is its intense focus on a single phenomenon within its real-life context (Crowe et al., 2011, p.4).

There is no prescribed template for data collection, for that researchers are encouraged to adopt methods of data collection that seems appropriate, convenient, and feasible, but scope, time and definite boundary must be set (Marrelli, 2007). The recommended methods of data collection include but are not limited to questionnaires, semi-structured interviews, and multiple sources of data, with detailed step-by-step procedures (Eisenhardt, 1989, p.534). In defining the term case study, Swanborn (2018c, p.13) developed the broadest definition of case study in a split form as follows:

> *“Case study is a social phenomenon study that is carried out within the boundaries of a social system such as people, organisations, groups, individuals, local communities,*
>
> *in the case’s natural context,*
>
> *by monitoring the phenomenon during a period or, alternatively, by collecting information,*

*in which the researcher focuses on the details of social processes that unfold between participants, with their values, expectations, opinions, perceptions,*

*where the researcher explores the data using the research question,*

*in which (optionally), in the end, the investigator debates with the stakeholders in the study on their subjective perspectives, confront them with preliminary research conclusions, in order not only to attain a more solid conclusions."*

Case study is not free of its deficiencies even though it has numerous advantages. It provides an opportunity to study a real phenomenon specifically in an exploratory way (Yin, 2009). It can give insight and understanding of the unfolding knowledge of complex situations in social activities.

Its drawback arises from its inability to tackle major concerns that Swanborn raised (2018a, p.182). Some concerns are that there is no specific format for reporting the result of a case study. Another concern is that having different audiences in mind raises a question of whether different reports should be provided for every composition of diverse audiences. Reporting with several reports for various audiences is not an effective use of resources and may not be better than composing one report that encompasses all recognisable parts and with all the information for each audience. This then makes it less important to worry about what form the report takes (Swanborn, 2018a, p.182).

It is also cautioned about errors that may arise during data collection when involving the intensive and extensive data, mainly the qualitative and quantitative elements in drawing conclusions to the data analysis. Swanborn (2018b, p.140) advised that differences between intensive and extensive do not sometimes coincide with the quantitative-qualitative distinction, while treating the difference between kinds of data (words or numbers).

### 3.4.3 Qualitative data analysis

In handling the qualitative part, many approaches such as thematic analysis, narrative analysis, phenomenological approaches can analyse data. Since the phenomenological approach (Finlay, 2009) may not perfectly espouse mixed methods because a mixed methods version of phenomenology has not been formally conceptualised (Mayoh & Onwuegbuzie, 2015), that eliminated it from being a likely option. Narrative analysis (Creswell, 2013) seeks the researcher's inclusiveness and participation in the sense that there's a role played by the researcher; however, I did not participate in the course. More so, in the interview context, the researcher must respond to emerging narrative expressions; storytelling is central to doing such research. Grounded theory is another alternative, but it was not fit as I did not intend to develop a theory that will explain the study (Corbin & Strauss, 1990). Grounded theory in its original form expects the researcher to collect data and analyse without a preconceived theory since theory will emerge from within the study. However, I had already selected Kearney et al.'s (2012) social cultural theory for this study and that disqualifies the grounded theory.

As a result, I chose to analyse themes by thematic analysis (Braun & Clarke, 2006), a text reduction approach where classification of themes rises into groups through a succession of interpretations (Creswell, 2013). Conducting a case study with the selected mixed methods in a review of mobile learning experiences of engineering students appeared to be the most suitable option to address the posed research questions.

### 3.4.4 Quantitative data analysis

Social network, message, and statistical analysis are used in addressing the fourth research question. I selected this approach because I want to find definite answers to what transpired during collaboration amongst students. Collaboration can only be thoroughly investigated through analysing of quantifying values and magnitude of influence among collaborators, i.e., students in a mobile learning setting (Reychav et al., 2016). This implies that a qualitative approach alone cannot be adequate.

## 3.5 The Research Method

There are specific data collection methods that I adopted, and these are grouped into two. Data collected for qualitative and that for quantitative analyses. I used the semi-structured interviews for qualitative analysis and sourced data for quantitative analysis from the mobile social networks, message and content transmitted by the students during their interactional activities in collaborative learning and practices. I used eighteen participants/students. Interview is recognised as a good source of data in a case study (Swanborn, 2018b, p.3). The initial test I did with a few students (eight of them) informed me of the boundary especially since the study embraces a case, that the mobile network must be bounded if it is going to be studied (Borgatti et al., 2013, pp.3-18). And since this study is investigating only learning that occurred with the mobile devices such as cellphones, smartphones, ipad, ipod, tablet, and phablet, laptops and movable desktops are not counted as mobile devices in the context of mobile learning in engineering (Ashfaq & Sirshar, 2018;  Choi et al., 2014). And knowing what the students used helped in framing the contents of the questions that feature in the interviews. Along the line of the research, I made a reflective journal of my thoughts and experiences that emerged as I progressed.

### 3.5.1 The creation of interview and quantitative data acquisition procedure

Interviews play the role of revealing the views of the participants in the research study (Mann, 2011). In interview, initial questions are conceptualised as generative with or without a set of specific questions that will provide the focus required to lead to data collection (Agee, 2009).  As an interviewer tries to bring out information that already exists with the interviewees, in the interview, the steps and actions of the interviewer finds the pre-existing truths (Kvale & Brinkmann, 2009). The criteria for what should be studied, who should be interviewed and how many, why is it relevant to do so, and how should the subject matter be studied guide the draft of the interview questions (Nathan et al., 2019, p.49).

The semi-structured nature of questions allows the interviewee to answer back and forth without sticking to a formal structure of answering the questions. A small number of participants are recommended for a study that uses the semi-structured interview (Drever & Scottish Council for Research in Education, 1995). I selected an open-ended interview type to enable students' fullest thoughts about mobile learning. Open-ended questions may be used alone or in combination with other interviewing methods to explore an in-depth topic so as to comprehend the system completely, and to find potential causes of observed feelings (Weller et al., 2018, p.2).

For the interview, I thought of a procedure that inquires from participants their view about the mobile learning in engineering, explaining what kind of engineering educational activities that can be accomplished using mobile tools and those that cannot be accomplished. In addition to that, getting enough information about their mobile learning and its challenges. For me, to get thorough answers to the research questions, I endeavoured to explore their understanding of the individual factors that influenced their choices of adoption of mobile learning. I asked the participants to re-think the mobile technology they had used and retrieve the thought about its types, kind, compatibilities, handiness, operability, and personal experiences in learning fulfilment. And I informed them that those are what would aid them in answering the interview questions appropriately. I offered an example of commonest mobile learning that a student does in engineering as a clue for them to capture the direction of the interview. I avoided imposing a timescale to the participants. In identifying those effectual questions that are worth using, I discussed the interview procedures with my supervisor and received positive feedback that led to my interview resumption.

Research procedures emerge from and support diverse theoretical traditions in social problems (Marvasti, 2018). The theoretical lens I selected identifies and investigates the social problem in this context. The procedure for quantitative data collection was guided by the three traditions in Kearney et al.'s (2012) model on mobile learning adoption which are authenticity, personalisation, and collaboration. Those three were considered in terms of a few metrics measuring social phenomenon that can be explained in the light of collaboration, and those are helpful in explaining the student's learning behaviours. The criteria require that measurement of social phenomenon produces results that are real numbers that are interpretable. Measuring the social activities involves use of numerical analysis that are acceptable in the field of social science. Mobile social structures are products of social activities and can be measurable using numerical analysis such as social network analysis. Quantitative data that will be analysed have conditions that necessitate their category selections.

#### 3.5.1.1 Pilot study

I conducted a single pilot test for this study with the same sample population. The rationale behind this test was to consider if the sample population and the type of engineering course envisaged is the best fit for the research work. Electrical courses play a vital role in all other engineering fields, it is a relevant field of learning that benefits all other engineering disciplines (Arfa et al., 2010).

In Creswell (2013, p.133), it suggests that pilot testing aids in refining the research structure and steps basically by directing where to modify in the interviews. The advantage of undertaking a pilot-test phase is that it enlightens a researcher's inquiry process and direction through the research especially in the qualitative section of a mixed method, and it provided a way for the research project. Kim (2011) revealed that a pilot test helps to: locate issues and obstacles related to recruiting potential participants; reflect the relevance of the process and its difficulty in conducting inquiry and modifying interview questions. It also paved the way to investigating the feasibility of collecting and analysing quantitative data - a part that I esteemed to be of importance in studying the technicalities involved when students adopt mobile technology to learn.

My interest was to be convinced that the students really use mobile technology to learn engineering. I consulted instructors who teach courses in my engineering department to know which segments that have used mobile learning. With their answers, I consulted the students who did those courses with a brief interview to get their views about mobile learning and if it exists among our engineering students. The students informed me of locations where they usually adopt mobile tools to learn, such as engineering tool websites, Apps, blog and social media. I therefore asked eight students their permission for an interview. I had an interview with the eight students of engineering, two students came from each level, from the second year of the engineering programme to the final year. Ranges of mobile devices they use fall within the 2nd and the latest (fifth) generation (2G to 5G). the majority of the students use the smartphone, which has been the most affordable mobile learning tool because of its enhanced features (Mizouni et al., 2014). The interview with them helped me to understand the concerns about using mobile tools in learning and how to develop my theoretical framework for this study. And it shows that the basic issues that constructed their mobile complexity is socio-culturally connected. That students struggle to own their ‘diverse content’ learning and interrelate among themselves in a least technology-supported setting became obvious. Amid them are the successful as well as struggling students. The answer to their learning support needs are mostly provided by mobile learning. Identifying the characteristics and connections among structure, agency, and learning culture which the students use, guided my selection of a theoretical framework.

### 3.5.2 The interview questions

Semi-structured interviewing is a very flexible practice for small-scale research. It is not suitable for studies involving large numbers of people, but is most helpful in case studies (Drever & Scottish Council for Research in Education, 1995). It equally refined my interview skills, steps to follow and the important questions to ask. I adopted the single individual interview rather than group. The one-by-one person interview is a valuable method of gaining insight into students’ understandings, perceptions, and experiences of a given phenomenon and it contributed to thorough data collection (Drever & Scottish Council for Research in Education, 1995).

The drafted questions were in a semi-structured format. The format allowed the students to divergently import new ideas to add to their responses to questions of the interview.  It allows participants and the researcher to deliberate on the context wholly. In a semi-structured interview, the interviewees have some fair level of freedom in what to talk about and how to express it (Drever & Scottish Council for Research in Education, 1995).

I developed a total of twenty-four interview questions for the qualitative section and one question for the quantitative section that covers the measurement of interdependence on participation and interaction. All the semi-structured interview questions covered the range of concepts viewed through the theoretical lens (see section 1.5). Seven questions centred on space and time; seven questions focused on authenticity; ten questions focused on personalisation; one question focused on collaboration, and the three matched all the elements. A detailed list of the semi-structured interview questions is in Appendix Two.

In addition to the semi-structured interview, information from the mobile engineering learning checklist also helped in concretising the result of the data analysis. The checklist document comprises four traditional laboratories, namely; power, telecommunication, control, and electronics, and all courses the students take in electrical and electronic engineering from first to final year. The students are expected to tick options of laboratories and courses they had accomplished, or can do, with mobile learning.

### 3.5.3 Institutional overview - sample population for the study

The sample only comprised of electrical and electronic engineering students. For me to capture the scope of engineering learning that was done in the faculty of engineering and precisely the electrical and electronics field, I consulted the course description of the Federal University, Oye-Ekiti, Nigeria, and the list of courses they run. The reason for reviewing this document is to be sure that ideas revealed by the participants of this research during the interview matches what are contained in the documents of engineering. A class semester's activities done in the department by mobile learning during a semester of university's industrial action were covered empirically in a small part of this study.

## 3.6 Data Source Summary

Data were the transcripts of interviews gathered by the researcher. There were eighteen interviewees whose data were used. They only had experience of one mobile learning platform. A minimum level of knowledge and skill was used as Papanikolaou and Mavromoustakos (2006) mentioned that adequate knowledge of characteristics, peculiarities and constraints of the various mobile devices and technologies used in mobile learning is a critical factor in this context. So, eighteen emerged as having knowledge of at least two out of the four-fold locations of mobile learning - LMS, Mobile Apps, Social Media, and Toolbox. These eighteen participants had credible experience for a minimum of four years. All interviews with respondents were recorded in November 2020. Data for the quantitative segment were derived from a dataset built by the counts of messages transmitted on two social network sites.

### 3.7 Selection of Participants

Purposeful, sometimes called purposive sampling, is a technique largely adopted in qualitative research for the identification and collecting from a selection of information-rich cases for the most effective use of limited resources (Patton, 2002). This covers identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Creswell & Plano-Clark, 2011). In addition to their knowledge and experience, Bernard (2002) and Spradley (1979) note the importance of availability and willingness to participate, and the ability to communicate experiences and opinions in an expressive and articulate way (Palinkas et al., 2015).

Although the samples for qualitative inquiry are generally assumed to be selected purposefully to yield cases that are “information rich” (Patton, 2002), in purposive sampling, there are no clear rules for conducting purposive sampling in mixed methods research, particularly when studies have more than one explicit purpose (Palinkas et al., 2015, p.534).

Purposive sampling is adopted for the characteristics that are important in representing a sample. The choice is led by the class size and that electricity course being a core to every engineering discipline. The study used students of electrical and electronic engineering from the Federal University, Oye-Ekiti, in Nigeria where I teach, and participants were selected through some screening questions administered using an online survey, which was thrown open to all students of the electrical and electronic engineering from 400 to 500 level students (see Appendix One for the online screening question). Use of only 400 and 500 is based on an important factor; these are students that have already experienced an engineering industrial experience and a high-level of academic knowledge. The screening helped to find participants who had the required experience, and that is basically for the qualitative segment. Initially, this study scoped twenty-one participants, one participant did not show up, and two participants' data were dropped because of inadequate skills and experience which they revealed during the interview session; however, data of eighteen participants were used because of their knowledge and skills in the use of mobile learning in electrical and electronic engineering. Only during the quantitative approach on the social sites were all students who engaged in online learning required. There are seventy-four students who participated in their online learning on social sites using their mobile devices and these are from only fourth year students. The twenty-one interviewees comprised of a few members of the seventy-four online students. One student missed his interview, two did not provide adequate knowledge of the context, and I continued with eighteen students. The students indicated more interest in participating in the interview probably because they used mobile learning to accomplish one departmental course in the ending of the last year 2019.

| Student’s level | Number who indicated interest to participate in interview | Number who participated in online mobile learning |
|---|---|---|
| 200 | 0 | 0 |
| 300 | 0 | 0 |
| 400 | 16 | 74 |
| 500 | 2 | 0 |

Table 3.1 The distribution of the participants

### 3.8 Researching as an Insider

Insider-researchers are considered very suitable in investigating case study research (Unluer, 2012). The work of Bonner and Tolhurst (2002) identified two key advantages of being an insider researcher. First is that the researcher has a greater understanding of the culture being studied and does not change the flow of social interaction unnaturally. And secondly, the researcher has an established intimacy which helps both the telling and the judging of truth (Unluer, 2012, p.2).

The pragmatist perspective allows the researcher to present the data cogently in more practical ways. For that, the researcher’s connection to the participants and university must be recognised to justify the validity of claims decrypted from the analysed data. Notwithstanding that researchers can be an insider, the question concerning the likelihood of the researcher's closeness with the participants to corrupt the trustworthiness of the research result came from Griffith (1998, p.361). To handle that, I discussed with my supervisor and it was approved by the ethics committee that I can use an administrator, as a gatekeeper, and the administrator reached the students directly and this research involved only students. I got the students' consent forms from the administrator in the Department of Electrical and Electronic Engineering. In addition to that, all ethical guidelines were duly followed. The use of social media sites for research requires careful attention to ethical guidelines. Ethical guidelines are used to prevent infringement of an insider researcher's influence from meddling with the data or disrupting trustworthiness (Rapley, 2004, p.80). A range of ethical concerns are addressed when research involves researcher and colleagues or closely related individuals. The researcher must meet or discuss with faculty or supervisor about the ethical guidelines (Rapley, 2004, p.79). And for that, I consulted the faculty through my supervisor for checks and approval. Ethical issues are discussed further in section 3.9.1.

As I did not teach the courses used in this research, I did not in any way influence the students' participation and their participation was not tied to their performance assessment. I am a lecturer in the same department and therefore I stand as an insider researcher. Despite the benefits of insider researcher to authenticity and validity, there could be bias sometimes. Problems arising from too much familiarity may lead to loss of objectivity; the researcher having over confidence, or prior information about the research setting which may create prejudice (Unluer, 2012).

The duality of roles sometimes confronts insider-researchers. And that makes them struggle to balance their insider role as an instructor, and the researcher role (DeLyser, 2001; Unluer, 2012). I understood that the real-world practice that those students are doing are not adequate, and their skills' level has been negatively affected. My long stay with them revealed to me that they learn largely through their mobile tools but the issue is the lack of proof of expertise in it. The engineering department understood the importance of the research and its potential contribution to teaching engineering and therefore facilitated my research to find what goes on with the students' learning and insight to improve it. The department vested hope that only an insider-researcher could investigate mobile learning in the real engineering perspective.

### 3.9 Data Collection and Analysis

A virtual method of data collection for the qualitative segment is recommended where restriction exists (Braun et al., 2017). Two sources of data were used in this study, qualitative and quantitative data sources. There are four parts of the theoretical framework: spatiality and temporality, authenticity, personalisation, and collaboration. The source of data that deals with spatial, authenticity, and personalisation was audio-recorded interview data that are transcribed and qualitatively analysed by thematic analysis. The source of data for collaboration is the mobile social network that was developed by the students' interactions during the semester in one course. I connected to those two online sites which they used for the course to build my dataset. And finally, I kept my research diary and wrote down observations that emerged during the research journey.

### 3.9.1 Steering the interviews

An opinion poll was used to select the most suitable students, i.e., those with adequate knowledge of mobile learning in engineering, who voluntarily participated in the research. After collecting twenty-one students, they were prepared to be involved in the semi-structured interview. However, sixty-six students signed the participant's consent form since their information was needed for the analysis of the social networks.

Conducting the interview was accomplished through internet telephone and video calls. At the start of the interview, each interviewee confirmed that they had received and signed the participant's information sheet (PIS) and consent form. They received the PIS and consent form and read them, signed, and submitted them. The anonymity of all the participants was confirmed. I detailed what the research is all about to them. I reminded them that they are free to withdraw any time they want within two weeks, and that the data of withdrawn participants will be erased and destroyed upon withdrawal. I confirmed that they were satisfied with recording the interviews. I gave them the opportunity to ask questions and express their views about the interview process.

The participants filled out the Mobile Engineering Learning Checklist (MELC) and submitted them at the end of each interview. The interviewees were given the questions ahead of time so that they could be ready for interview. Each interview period lasted between thirty minutes and one hour, and a digital audio-recorder recorded each interview. The semi-structured interview questions are shown in Appendix Two.

In the repeated interview, to ask their reasons for online actions, I asked them open-ended question selected from the same semi-structured interview questionnaire, this time based on communications on the two social network sites. Those two SNS sites were used by the entire class for learning informally for three months in the last quarter of 2019.

### 3.9.2 Transcription of interviews

The recorded audio data were exported to *Otter.ai* software running on my personal computer to assist in fast transcription with minimal manual editing to fix errors such as omitted letters. I transcribed all eighteen recordings and ran through all of them on a separate day to cross-check if there were errors or omissions anywhere. I confirmed that all data were properly transcribed by listening to the audio recording again and compared it to the transcripts, stored them in my computer and uploaded them to Lancaster University's server. For sentences in the transcripts that I was not sure of their meaning, I returned to the interviewee to confirm what had been said. I used aliases such as E1, E2, E3, E4,… $E_n$ , to denote the participants to avoid confusion in handling the data and to make the data anonymous.

### 3.9.3 Thematic analysis

Two forms of thematic analysis could be applicable to derive themes - inductive or deductive (Braun and Clarke, 2006). Inductive analysis allows the data to determine the themes and the deductive analysis involves coming to the data with some preconceived themes that are expected to be found reflected in the data based on the theoretical framework or existing knowledge. I used the inductive approach.

The thematic analysis (TA) is theoretically flexible, not atheoretical (Braun & Clarke, 2006). The TA could be inductively or deductively theory related. Even though TA may be flexible, poorly demarcated, and rarely acknowledged, yet it is a broadly used qualitative analytic method (Roulston, 2001; Boyatzis, 1998).

Thematic analysis is a method for recognising, analysing, and reporting patterns (themes) within data, and minimally organises and describes a collected set of data in rich details (Braun & Clarke, 2006). I selected TA because it offers a more detailed and subtle difference in meaning of one specific theme, or group of themes, with the body of data. This may relate to a specific question or area of interest with the entire data (Braun & Clarke, 2006). In a mixed method research, to develop rigour and trustworthiness, Nowell et al. (2017) recommend the conventional step-by-step procedure, I enumerated in the subsequent lines, to contribute a resolute approach to thematic analysis in order to systematise and raise the traceability and confirmation of the analysis. I adopted the Braun and Clarke thematic approach to analyse the data and adhered to cautions that help avoid lapses.

*Implementation of the Braun and Clarke's thematic analysis;*

There are six phases guiding the process of thematic analysis recommended by Braun and Clarke (2006, p.87). These are sequential, but iterative steps that I adopted and these are:

*Step One: Familiarising myself with the data*

I familiarised myself with the data and got deeply engaged in understanding of it. I read over the data in an active way before I started the coding process. Reading through it all helped me to gain an imagery of the scope and width of what to analyse.

*Step Two: Generating initial codes*

I generated initial codes to identify the noteworthy statements within the body of data. I used the conventional, manual method to prepare and arrange and analyse the data. I handled each transcript one after the other, coding separately. The conventional method, though laborious, produces a better valid result.  I adopted the inductive technique to create the codes while I added each transcript. I identified each code and assigned a name to them. Doing that is to describe the features of the data and with details of how it is different from other codes that may be alike. I kept refining the codes while I did each transcript. I anticipated that the first few transcripts I handled may have influenced the overall outcome of my analysis; for that I took notes and marked ideas for coding that I might come back to in the next steps.

*Step Three: Searching for the themes*

After I coded and collated, I organised a list of codes I identified from the entire data. As this phase focuses on the broader themes, and connection between the codes, I sorted all the codes into potential themes and collated all the code data that I had extracted from the identified themes. I used the mind-mapping strategy to identify and combine codes. I continued steps three, four and five in an iterative pattern by searching, revising, and defining the themes.

*Step Four: Reviewing the themes*

I reviewed and refined the themes to ensure that they were appropriate. Then I collapsed them to form a coherent pattern and established my first thematic map. Then new themes emerged, and the codes were adjusted to match the emerged theme.

*Step Five: Defining and naming themes*

This was achieved by continuing to analyse and refine the themes in such a way that the story behind the data emerged. I determined what aspect of data each theme captured.

*Step Six: Producing a report*

I produced the final analysis and write-up of the report after I had a set of fully worked-out themes. According to Braun and Clarke (2006, p.93), the work of the report is to tell the complicated story of my data in a way which convinces someone of the merit and validity of my analysis. I consulted my supervisor for a review of my themes, to get a persuasion that the results were reliable.

### 3.9.4 Building datasets for quantitative analysis

Data are built from two Social Network Sites (SNS) and the study allowed an impulsive and free learning which meant that the students actions were not influenced by the investigation. It was for the benefits of finding the true and natural real-time learning activities on mobile social networks. Choice of sites resides on the use of the class's course blog which is the main stream of their online activities and secondly the Facebook group was selected as their most used social network (Bicen & Cavus, 2010, p.5868; Catanese et al., 2011 ,p.1; Giunchiglia et al., 2018, p.177).

The two closed SNS are www.ikole-engineering.blogspot.com and their Facebook group titled "Electrical Power Principle Group", https://www.facebook.com/groups/2803539939675118. Those sites are closed in the sense that only permitted members can join. And the students confirmed that all activities that transpired on them were solely accomplished using their mobile devices.

For me to build the datasets from those two SNS, I manually entered the counts of interactions manifested by posted information, comments to a posted information, reactions to a post or comments from everyone, in an MS

Excel spreadsheet. I counted only a piece of interaction as one only if it had a returned response. A count is called an interactive link on social network only if it has a returned response (Borgatti et al., 2013; Weller et al., 2018). After I entered all the elements of interactions into a spreadsheet, it became my dataset. The dataset of each site was exported to the social network analysis tool, called Gephi[8], in stage two.

#### 3.9.5 The social network and message analysis

Collaboration encompasses conversation and data or information sharing in a mobile learning environment (Kearney et al., 2012; Reychav et al., 2016). Three quantities that students' learning produced are analysed here: the social network structures, the contents or messages, and the conversational pattern.

##### 3.9.5.1 Social network

Users' perceptions are explorable, but in online interactions users do not follow or count the capacity of their educational and social influence, as actions within learning circles are not visible, hence software is used to accurately deduce and analyse activities quantitatively (Borgatti et al., 2013). I used the social network analysis to inspect connections, and the engagement and participation measurement would use simple message analysis (McInnerney & Roberts, 2009). Activities among users that are connected in

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[8] https://gephi.org/

a network are analysable (Borgatti et al., 2013). I checked the inputs from the online participants using message analysis. There are other approaches such as natural language processing, and text mining (Aggarwal & Zhai, 2012). However, this study selected simple message analysis by McInnerney and Roberts (2009) for its simplicity and application in inquiring about students' information exchanges when they engage in learning. McInnerney and Roberts (2009) was used for educational investigative purposes unlike natural language processing and text mining that are universal in application.

In the second stage, I analysed separately the interactions of each (blog and Facebook) using Social Network Analysis. This investigated the collaboration between the nodes (i.e., students) and their connections using their properties (posts, comments, reactions). I focused on the nodes, and their linkages by connective properties such as reactions, comments, and posts are the edges (Olivares et al., 2019, p.3). I investigated what they could do in the mobile social networks; the prominent nodes are interviewed there after the network analysis, to understand how they collaborated for learning purposes. The learning activities on the mobile social environment are observed based on an indication that the tools they use for those activities - messaging, documenting, troubleshooting, simulation, data transfer, etc., are solely on a mobile device.

I used two social network analysis tools, *Gephi* was used to analyse the dynamics of interaction between the nodes and their links, and *yED* software used for visualisation, to plot the network for a simplified and comprehensible network map. These analytical tools were selected because social network analysis is used to investigate learners' interactions in mobile learning (Borgatti et al., 2013).

The network metrics that the analytical tool investigated are the following:

*Centrality*: This informed an understanding of the homogeneity of the network. I measured the value of a node that featured in the network. It helps to explain the visibility of a node (i.e. student) and information about the power control in the network (Martínez et al., 2003). In this study, measuring centrality appears in three forms - degree, closeness and betweenness.

*Degree centrality* value is grounded on the direct connections with a node.

*Closeness centrality* value is grounded on the distance among the node and all other ones, such that the highest value is given to the node with the lowest distance with others.

*Betweenness centrality* value is grounded on how many times the node is part of the shortest route between two other nodes. Degree and closeness centralities may be calculated taking account in-, out-, or ties in both directions (Claros et al., 2016, p.191 ; Valente et al., 2008).

*Network density* or *density*: Density measures the proportion of ties in a network relative to the total number possible, without considering the distribution of connections among nodes. I found how thickly or densely populated the connection of nodes were, and that tells how information was easily distributed among the nodes in the network (Wasserman et al., 2005).

*Sub-groups or sub-network:* These tell that the sub-network exists within the main network. It recognises the sub-structures of the network. It is generated from a sub-set of nodes that are strongly tied to each other and this is defined by a minimal number of tied nodes and a minimum weight on their connections (Wasserman et al., 2005). Network's size, strength or total number of cliques also contribute to a clique's information. Finding this helped me to understand who are in a cluster and why those students (nodes) emerged in that cluster. It identified their pattern of collaboration (Claros et al., 2016; Reffay & Chanier, 2003).

However, the mathematical formulas that manipulate those metrics are embedded in the *Gephi* software, used for analysis. So, my role was to input the datasets values into the software application, and it produced metric values, i.e. results. The reason for selecting these network metrics as points of interest for investigating the mobile learning collaboration is that Claros et al. (2016) recommend that in the study of online collaborative experience, it is best to measure the mobile social process in that collaborative learning experience, and should consider the centralities (betweenness, degree, closeness), density, and cliques.

#### 3.9.5.1.1 Indicators or Index of Measurement

The statistical relationships of those metrics are computed using descriptive statistics by exporting their values to an MS Excel spreadsheet and computing their mean, standard error, median, mode, standard deviation, count, and confidence level of post, comments, and reactions of the two SNS. And this will indicate the high and low values and provide insights to the nature of a mobile collaborative site that may be adopted for students in future times.

#### 3.9.5.2 Message analysis

I used this approach to superficially analyse the content found in the interaction among the students. I counted on-task and off-task messages and percentage participation. The Message Analysis (MA) is chosen for its overwhelming role in giving meaning to participation as well as being capable of evaluating learning engagement. Interaction occurs when a group of the online members refer directly or indirectly to prior messages in a discussion, while staying on a topic. All responses make up participation in the conversation, but only on-task continuous threads count as interaction (Roberts, 2004, p.218).

Unlike the SNA, the message analysis goes beyond looking at the connection between nodes and the ties that bind them up; these chains are link wrapping some amount of sentences in the form of discussion on post and comments with the exception of social media site reactions such as  ‘Likes, Love, etc.’ I used the MA to find the level of meaningful conversation and data share that went through the learning process on the SNS.

##### 3.9.5.2.1 Participation

Participation is measured by counting the number of messages and statements made by individuals and the group to the other participants and the instructor. Participation forms the essential that supports interaction. Both groups and individuals within groups can be compared in their levels of participation (Roberts, 2004).

#### 3.9.5.2.2 Interaction

The analysis of interaction is crucial and it is a centre of all the characteristics of collaboration. I identified every statement into the broad categories of on--task and off-task messages. Off-task statements may include community building statements that are important in creating an environment that supports collaboration, such as introductions, reference to status or experience, or similar statements. Off-task comments may also be totally unrelated to the assignment, such as discussing the weather. Off-task discussion may be a distraction but may also serve as an icebreaker or means of leading into or closing a discussion (Roberts, 2004, p.227). I counted only the on-task statements and those useful off-task messages which are those off-task messages that could be an icebreaker during the discussion. In this study, the MA measures the participation and interaction basically of the online collaboration.

### 3.9.6 The interview questions and questions for quantitative data analysis

De Laat et al. (2007, p. 88) proposed that interactions among members in online learning groups can be represented easily and explored using SNA, which provides additional useful analytical data about the activity and relationships of the online members. For that, questions answerable by the metrics become of interest to me. The questions were drawn from the context of the major research question and can be viewed through the lens of the framework used for this study.

Based on Borgatti et al.'s (2013) recommendation of a tool for investigating learners' interaction, and the recommendation of Martínez et al. (2003) on the relevance of centrality and density, I studied the meaning of these terminologies - Centralities and Network Density - with respect to the context, and developed questions whose answers would explain the meaning of these terms with real values. The performances of the nodes triggered a repeat interview to the leading students in the network, i.e. nodes with high level of network traffic as indicated by the network analysis and plot outcomes.

### 3.9.7 How research questions are answered

These are how the research questions were answered:

1. The perceptions are evaluated using coding and thematic analysis.

2. The online interactions were investigated quantitatively.

3. Another round of interviews were conducted, with the students whose interactivity levels are high or low, to inquire how and why the learning structures that emerged have happened. This stage sequels the SNA and MA phases.

4. Then further coding and thematic analysis was used to concretise the result of step 3.

### 3.9.8 How to finalise the analysis of data

After the online activities were examined using SNA and MA, I used a mathematical (statistical) tool to extract the SNA data analyses and visually represent the online actions and put the data into a new spreadsheet to work on them using descriptive statistics. The descriptive statistics from the MS Excel spreadsheet can be applied to compute data efficiently. I imported from the SNA data to a spreadsheet where I computed the mean, standard deviations, etc., to add more meaning to network metrics.

The following Table 3.2 shows the summary of all the data analyses in this study.

| | Research Question | Data Collection Method | Who/where the data is collected from | Method of Analysis |
|---|---|---|---|---|
| 1 | When and where do students use mobile technologies for informal learning activities? | Semi-structured interview | All the participants | Qualitative |

| | Research Question | Data Collection Method | Who/where the data is collected from | Method of Analysis |
|---|---|---|---|---|
| 2 | How do students perceive the authenticity of practices performed through mobile technologies? | Semi-structured interview | All the participants | Qualitative |
| 3 | How do students create their own learning by customising activities? | Semi-structured interview | All the participants | Qualitative |

| | Research Question | Data Collection Method | Who/where the data is collected from | Method of Analysis |
|---|---|---|---|---|
| 4 | How do students collaborate on social media for learning purposes? | (a). Researcher will manually calculate online inputs (message post, problem, or task from participants) and use them to build a dataset (for sites where mobile is used publicly)<br><br>(b). Semi-structured interview (for where it is used as stand-alone) | Basic locations are the Facebook and class blog<br><br>Participants captured on social network structure | Quantitative (Social Network Analysis, and Message Analysis)<br><br>Qualitative |

Table 3.2. Summary of the Data Analysis Plan

## 3.10 Ethical Considerations

Ethics exist within a social context, and that reminds us of the importance of including an ethical perspective in the very foundation of a research project (Naoi, 2006). The moral integrity of the researcher is a critically important aspect of ensuring that the research journey and the researcher's findings are trustworthy and valid (Naoi, 2006). The established codes of research practice show the importance of ethical issues in research (Cohen et al., 2018). In the light of that, Patton (2002) provides an ethics checklist to consider as a researcher proceeds with a research project (pp. 409-410).

Ethical guidelines are observed on the internet-sourced data (Townsend & Wallace, 2016). A minor segment of this research derived its data from an internet surface. There are key ethics concerns which researchers are advised to keep in mind when considering implementing or evaluating an internet-mediated research study and those concerns were adhered to (Hewson & Buchanan, 2013). These concerns guided the demand for ethics and they included: the public-private domain distinction online; confidentiality and security of online data; procedures for obtaining valid consent; procedures for ensuring withdrawal rights and debrief; levels of researcher control; and implications for scientific value and potential harm (Hewson & Buchanan, 2013, p.1).

As an educational and social research, the ethical guidelines established by the Lancaster University Ethics Committee and FUOYE (my university) were critically obeyed and supervised by the University's Ethic Committee and my supervisor. Both institutions have varied ethics formats procedures and policies when doing research that involves human subjects. All documentation accompanying the approval of ethics were duly supplied to participants, supervisor, and the ethics committee. This research was conducted in line with British Educational Research Association (2011) guidelines.

### 3.11 Summary

This chapter develops a template for a step-by-step approach to dealing with the research questions. At first, it opens from the theoretical lens the four constructs that bore four research questions and shows how each question is handled by viewing through the lens. The elements of this chapter explain how the mixed methods have been incorporated within the case study. It provided a chain of action for the entire study and it enables me to follow an organised sequence while transiting from one stage to another during the entire research. This chapter contains a researcher's map that guided me to find answers to research questions, and thereby also becoming a chain of evidence to ascertain the validity of results at the end of my research project.

# Chapter 4: Findings

This chapter focuses majorly on analysis of data and its findings. It covers an overview, data source summary, and research themes.

## 4.1 Overview

The purpose of the thematic analysis being adopted to investigate the case of mobile learning use in the Federal University, Oye-Ekiti, is to develop an understanding of the nature of the learning experience emerging from socio-cultural characteristics of pedagogy and provide awareness of identified issues that have shaped engineering education. The analysis of themes considered majorly the socio-cultural elements by viewing through the six sub-gauges, embedded in the adopted theoretical framework, that express the critical features of mobile learning activities of the participants.

## 4.2 Research Themes

Themes and sub-themes emerged when more than half of the entire participants' views and patterns are in accord (Braun & Clarke, 2006, p. 5), and the rule applies to all statements that are made throughout this chapter. The following is a report of the overall themes I discovered through my analysis of the data from the interviews, observations, and journal collections. Sample responses are used to support selected themes. For each of the participant's data, I analysed the raw data, produced the first order and second order themes, and then produced a general dimension. This was done one after the other, for all eighteen participants and themes were not repeated.

### 4.2.1 When and where do students use mobile technologies for learning activities?

The above question is research question one and it was designed to investigate where and when the students use mobile technologies to learn. After the analysis, one theme, ‘Spatial diversity of mobile learning’ bore three helpful sub-themes that emerged. The connection of themes with sub-themes as they emerged from the thematic analysis is shown in Figure 4.1.

These themes and sub-themes are derived from the entire data, i.e. transcripts of interviews using the procedures section 3.9.3 on implementation of the Braun and Clarke’s thematic analysis. Details of every theme and sub-theme as shown in Figure 4.1 are covered in the following sections and sub-sections sequentially.

The context of locations of learning covered technical and non-technical locations. The question that conceived this topic was borne out of the search for the place that is the basis of community and social life of the students and the space in which more creative activity take place. And for that, it takes ‘where and when’ the students do their learning activities with mobile technologies.

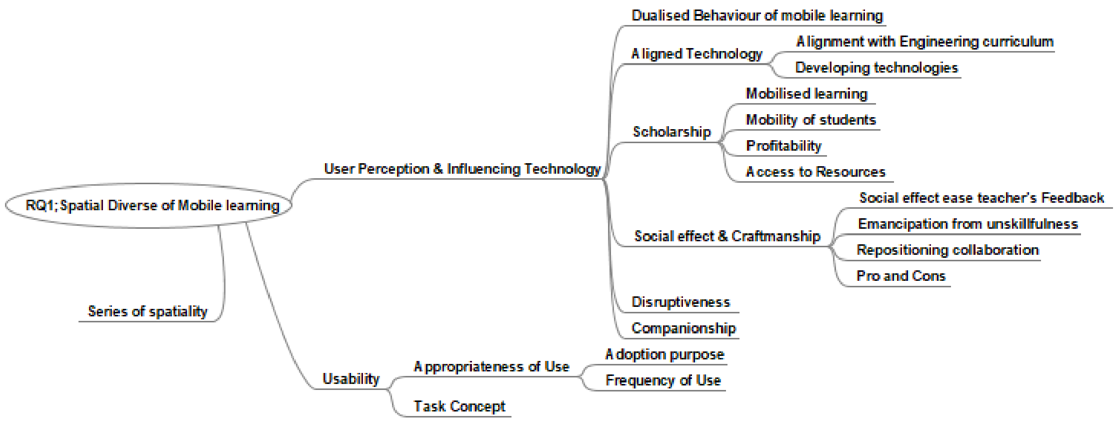


Figure 4.1 Thematic Map One

#### 4.2.1.1 Spatial diversity of mobile learning

It considers how the locations and when the students use the mobile learning is characterised by the following sub-themes: User perception and influencing technology, Series of spatiality and temporality, and Usability.

##### 4.2.1.1.1 User perception and influencing technology

Student perceptions of mobile learning and its technologies pushes to where and when they must use it. There were sub-themes that explained the user perception, namely: Dualised behaviour of mobile learning, Aligned technology, and Scholarship. Students expressed that persuasiveness of mobile technology would contribute to selection of location and time of learning with mobile tools. There are three sub-themes that explained technology influence, namely: Companionship, Disruptiveness, and Social effect and craftmanship.

#### 4.2.1.1.1.1 Dualised behaviour of mobile learning

All the students expressed two forms of provision of mobile learning. They believed that mobile learning has two forms, and this determined selection of learning places. The two forms are that mobile learning is tough or difficult, and it supports all platforms where the students learn engineering.

The analysis found that the toughness of mobile learning is expressed by students' levels as either a beginner, medium or expert. All the participants expressed that it is not easy for beginners especially in doing programming as many of the machine programmes involves writing of codes. The toughness also manifests when they try to navigate some of the platforms; it confuses them in the beginning but normalises after a few encounters. Respondent #1 said:

> It has not have been very easy to use our mobile application to start in especially in the aspect of programming where use of code is required.

Also, when they do engineering-practice and learn, all platforms (LMS, Mobile social media, Toolbox, Mobile Apps) are supported. They equally state its power to accomplish their academic purposes. An opinion from respondent #10 was:

> All those areas I have used, like YouTube, the Coursera, the Simulink, MATLAB, using the mobile phone to read PDF files, all of them has been very interesting. I used the Class Blog, the Facebook, YouTube, the Coursera, they are all internet-based. But those stand-alone I have

> used are the Adobe PDF that I used to read, we used to read PDFs. And the WPS, we also used that to read the PDF. They are not internet -based. And we have the one that is for both such as python programming. The Android has a higher version, 8.0 version. So, the lower version 7.0 and less don’t work all that well but with the 8.0 version and newer versions, everything works very well on them, on all those platforms.

#### 4.2.1.1.1.2 Aligned technology

The students’ perceptions about the relevance and relatedness of technology to their engineering education contributes to their choice of when and where to adopt mobile learning. They express that the mobile technologies are well aligned. And respondent # 4 said:

> learning has gone from hard copy textbooks to digital learning, and you must be updated with the use of all modern tools, all the mobile Applications give you an edge over tasks as they are fit for one task or another.

The analysis revealed these signifiers are what they meant by an aligned technology: alignment with engineering curriculum; and developing technologies.

##### 4.2.1.1.1.2.1 Alignment with engineering curriculum

The students believed that mobile learning aligns with engineering curriculum because it makes it possible for all the students’ tasks to be easier by putting them online and offline, thereby making the use of mobile technologies effective in learning engineering. Also, like the desktop, there is a provision for accommodating more engineering Apps that students use to learn, and those Apps complying to tasks they do. They do not face major technical issues as the students stated.  Respondent #15 said:

> So mobile tool is beneficial to us. I think the major issue we face is break in transmission, there are sometimes a network failure at a time when there is poor network coverage of location.

**4.2.1.1.1.2.2 Developing technologies**

In developing technologies, the students expressed that they are in the digital age and must live with the emerging technologies of the digital age. They expressed they are in electronic age of ‘no print.’ According to them, mobile technologies are their major tool; a technology that fits their age. Their perception validates why they engage in using mobile devices while attending a class lesson, even though they express that it drives learning.  Respondent #6 said:

> All I have to say is that the mobile device these days, you know we are a modern age, everything we do these days we do it with the mobile device. Yes, both in learning and other things, like the social media.

**4.2.1.1.1.3 Scholarship**

All the participants expressed that the perception of students that could influence when and where they will do mobile learning is dependent upon the scholarship. According to the analysis, four sub themes emerged to enlighten scholarship, namely; mobilised learning, mobility of students, profitability, and access to resources.

#### 4.2.1.1.1.3.1 Mobilised learning

All the participants' views about mobilised learning or mobility of learning were explained to be: mobility of learning is the transitioning of a learning process from one stage to another stage as the student changes location, e.g. a student explained how they engage deeply in a class discussion, with his mobile phone, in the bus, and immediately he gets to his home, he switched to another kind of learning process of solving engineering analysis.

#### 4.2.1.1.1.3.2 Mobility of students

All the participants expressed that mobility of students is changing learning behaviour orchestrated by changes in the student's location or student's decision to change location due to learning behavioural changes, e.g. the interest of the student to persist to study engineering analysis amidst the noisiness of the bus when he was in transit and ability to attain his learning goal or objective.

The students stated it mobilised learning by reducing the stress of moving large electronic devices around as they can find all in the mobile Apps such as oscilloscope, electronic boards – the breadboards, Veroboard, electronic components.

#### 4.2.1.1.1.3.3 Profitability

Students' perceptions that determine when and where they will adopt mobile learning are dependent on their level of awareness of the benefits of mobile learning. All the participants believe that it is truly good as it is boosting their academic performance:

- By teacher-student agreement, a portion of coursework is allocated to mobile learning only and they do it when time is running out.
- Providing ease of studying, being convenient, always keeping the students connected amongst themselves, leading to positive impact on all their course as it offers learning whenever needed.
- A learning pathway even though it could be distracting if not managed, that has been assistive and affordable.
- Creating a backbone for every student's individual or personal learning network.
- Encourages student learning, promotes their learning habits and behaviours.
- Providing convenience for research, learning, and does not distract students.
- It increases their wealth of knowledge. It plays an active role in doing their assignments and mini-projects, such as electronic circuit designs.

#### 4.2.1.1.1.3.4 Access to resources

Scholarship is functional with the availability of digital copies for students of textbooks, notebooks, component data sheets, etc.  The ability to access what is required for a task at any time and place plays an important role. A beginner may initially find it tough trying to gain access to full knowledge of how to do a task in a specific engineering App.  All the students mentioned that AutoCAD and MATLAB are highly useful engineering tools, but they lack a layman's guidelines or ease of use. According to the students, a beginner will definitely require assistance from a helper or teacher. Absence of a dummy layout on the application's user interface from where a novice-student can start learning is a big challenge to the students. However, some students said that there is easy access to resources, an easily downloadable textbook was due to medium file size, and this is quite encouraging.

Programming resources are easy to reach, and it encourages their scholarship. Respondent #17 said:

> So, when we are taught a thing in class in school about a particular circuit we use the PSPICE to run, we use it to test run the circuits which we don't really have devices that we can use in school to test run it.

In summary, the perception of the students that come from clarity of mobile learning and alignment to their learning needs will determine when and where the students adopt mobile learning. This concurs with Gan and Balakrishna

(2016) that identified user perception as one key factor in adoption of mobile learning by higher education students.

#### 4.2.1.1.1.4 Companionship

Two signifiers that emerged to describe this relatedness to students are in terms of influence on their personal life and on their studies. The persuasiveness of mobile technologies influences the mobility of learning and mobility of students thereby determining when and where they will study. Both learning mobility and changes in scholarship are controlled by the influence of technology. McKinney (2013, p.1) states that scholarship has changed through the modern instructional technologies that have been widely adopted today.

The inclination to use of mobile tools is due to influence. A student with low influence may seldom use the mobile, but a student with high influence will always be itching to use it. A combination of the persuasiveness of mobile technology and the passion or interest of students will determine when and where they will take up learning. The students expressed that they could take mature decisions in making choices irrespective of distractions or social effects.

The students perceived the following; that it influences them highly. Mobile learning has been influential in student everyday life by keeping them in an inquisitive behaviour of researching to know more since its tool is always handy. They believe that modern technology changes the drivers of education. Respondent #2 said:

> Mobile learning has influenced our lives greatly. There are two types of influence the mobile device can do in a student's life, we have the negative and positive influence. This is because we can use them to play game, and that's negative influence, and even some students use it to play games inside the class. For me, rather than playing games, there are a lot of positive things I can do with my mobile phone such as learning.

**4.2.1.1.1.5 Disruptiveness**

Students said that when they do not know what to use mobile tools for, they got trapped into using it disruptively, such as playing games with the mobile device at the wrong time. Students expressed that why teachers do hesitate to allow students to use mobile phones in the class is due to some students using them inappropriately. The students expressed that the indiscriminate use of mobile tools shows up when disruptiveness overtakes their scholarship due to loss of engagement in learning. And students do not appropriate it into profitable goals within engineering education. Respondent #1 said:

> We all have mobile devices connected to the internet but just that some students prefer to go on social media to get disrupted, not putting effort into learning things that can help them develop themselves.

**4.2.1.1.1.6 Social effect and craftmanship**

All the students expressed how their social effect and what they can do determines when and where they must adopt mobile learning. Three signifiers were born out of this sub-theme and these are: social environment enables feedback from teachers, emancipation from unskillfulness, repositioning collaboration, and cons and pros.

#### 4.2.1.1.1.6.1 Social environment enables feedback from teachers

The students decried that despite that some teachers dissuade the use of mobile tools during lessons, teachers use it to communicate to them by sending broadcast messages. Teachers also send emergency feedback to students using the mobile device. Under this discussion, the student outlined the following, that it is most likely that every student owns a mobile phone. It underpins the view of James and Versteeg (2007) who explained the unusual mobile ownership that is practised in Sub-Saharan Africa that contributes to massive mobile usage. According to a study of all Nigerian universities by Tsuma et al. (2013), it indicates that about 91.8% of the students possess mobile phones, and they embrace and value it for learning (Oyelere et al., 2018, p.468). The students emphasised that it is most likely every student uses a mobile device to learn because they use their mobile telephone to find any information over the internet.

#### 4.2.1.1.1.6.2 Emancipation from unskillfulness

Students expressed that there is an upgrade in their skill since they have adopted mobile learning. They could do a wide range of practices such as simulation, testing, designing, calibrating, measuring, programming, troubleshooting, wiring, and more. To them, it is an active tool that influences their software programming abilities.

#### 4.2.1.1.1.6.3 Repositioning collaboration

The students believed that interest to study together increases as the year progresses. According to them, in the year they joined the university, there were smaller numbers of mobile users and in their present level of study there is a high number of users, and it then enabled quick and easy sharing of textbooks and resources amongst students. It provides backbone or structure for group work. Respondent #7 said:

> Activities such as group learning enriches learning experiences because with the use of your mobile phones and mobile devices, we are able to go through the internet and get knowledge using the mobile phones, like most textbook I have access to them. So, to me, it has been helpful to my studies, and in communication, sharing of information among our peer groups.

However, forming mobile learning groups is prevalent. Students unanimously expressed their perception that they must weigh up the benefits and disadvantages of working in groups before deciding to join their mates for an online discussion. They outlined the following observations of an unorganised group learning.

#### 4.2.1.1.1.6.4 Cons and pros

While working in groups, there is distraction from peers. It creates Internet competition - too many users at a time. Some students believed that it is the same experience as when working as individuals and some students do not collaborate due to weak internet connectivity.

It provides learning space amongst students. More tasks become achievable and quicker as they share newly explored thoughts. New things are definitely learned by an individual. Because of the economic situation, as a developing country, students adopt a strategy to minimise internet cost, they gather to collaborate face-to-face, when there is poor or no network to discuss and share tasks, then they use stand-alone Apps to complete tasks and meet again to discuss results. Group learning provides opportunity for questions and answers that give more understanding. They believed it increased interaction; everyone develops a deeper understanding during group discussion. Students consider if learning amongst peers is necessary or not, and it also dictates when and where they will learn. Respondent #16 said:

> When we work in group, it is like going to be a fun and more understanding because we'll be able to share ideas.

In summary, how influential the mobile technologies are to the students will contribute to choices they make for when to use them for learning because how long they are attached to it tells what kind of activities they can do (Sibanyoni & Alexander, 2017, p. 20). All the samples of screen time of the participants' mobile devices were taken, and the average screen time is determined by dividing the total screen times by the number of students whose screen times were added (see Figure 4.2). The result shows that the student's average screen time is eight (8) hours per day and this covers time for doing both non-engineering and engineering learning activities. It concurs with the evidence that the way the students use the mobile technologies could impact students' academic life (Felisoni & Godoi, 2018). Figure 4.2 depicts the average mobile device screen time of engineering students, underpinning the influence of technology on the students. Mobile device screen time could be a verdict explaining its influence on the user (Kortum & Sorber, 2015, p.525).

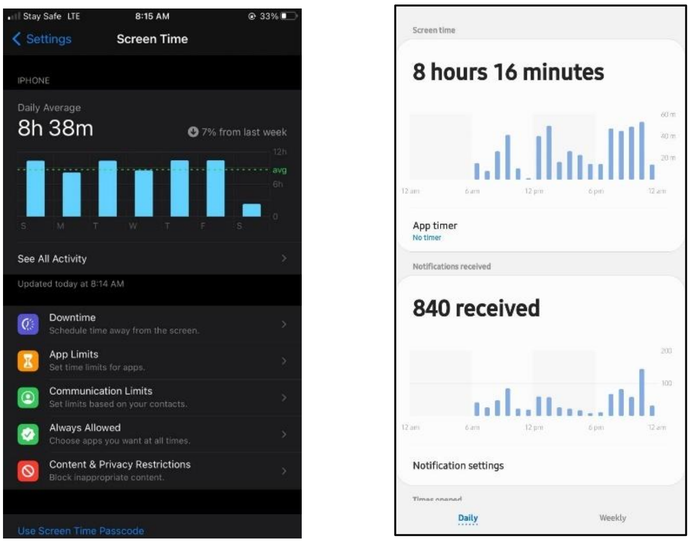


Figure 4.2 Samples of average 8-hour time of students' mobile screen time to illustrate the persuasiveness of mobile tools (Source: participants' photograph).

#### 4.2.1.1.2 Series of spatiality and temporality

This is concepts of what, where and when the students do mobile learning. All the students expressed what kind of tasks they do and where they do these, as those are determining factors to their space and time. After careful analysis of tools, tasks and location, there emerged four sub-themes, namely; Used online and offline, Used in-school and out-of-school, Tools used on sole and collaborative forms, and Categorised tasks according to mobile device specifications.

#### 4.2.1.1.2.1 Used online and offline

Two signifiers grouped the online and offline tools and tasks. The students stated that two conditions are tools and tasks they do with or without an internet connection in their device. Some tools and tasks are suitable for both conditions. Some tools are usable as stand-alone and some in both online and stand-alone modes. Students switching choices to online and offline is subjective. More students expressed that offline Apps are more important to them than online Apps because of their environment's high cost of internet. Respondent #3 said:

> There are applications I've used with internet; most I have used are offline. You know, internet is costly. There are some Apps that we use without internet.

##### 4.2.1.1.2.1.1 Online tools/tasks

These are the internet-based tools, platforms, and tasks the students are predominantly doing in engineering between their first year of entrance into the university till end of 2020. These are summarised in Table 4.1.

#### 4.2.1.1.2.1.2 Offline tools/tasks

Students used these without internet, some are internet-supported but can be used when cloud services are not required or when circumstances push them to. These are listed in Table 4.1.

| **s/n** | **Tools/Platforms** | **What students do with it** | **Online** | **Offline** |
|---|---|---|---|---|
| 1 | AutoCAD | Used for drawing and editing digital 2D and 3D designs more quickly | Yes | Yes |
| 2 | Arduino | Open-sourced used for designing interactive electronic objects | Yes | Yes |
| 3 | Coursera, Udemy | Taking free and paid online courses | Yes | |
| 4 | Fulcrum | Arranging workflows, automating data collection and formation | Yes | Yes |

| s/n | Tools/Platforms | What students do with it | Online | Offline |
|---|---|---|---|---|
| 5 | PSpice (Personal Simulation Program with Integrated Circuit Emphasis). | Used for simulation and verifying analogue and digital circuits | Yes | |
| 6 | Social Media- YouTube, Facebook, Blog | Learning (personal and collaborative), class discussions, lessons, presentation, sharing of files, textbooks, and data sheets | Yes | |
| 7 | Adobe, Kingsoft (WPS[9]), Microsoft, Videorder | These are the assistive tools they use, for reading, printing, organising documents, graphic designing, and downloading videos | Yes | Yes |

[9] WPS- Writer, Presentation, Spreadsheet

| s/n | Tools/Platforms | What students do with it | Online | Offline |
|---|---|---|---|---|
| 8 | MATLAB, Simulink | Used for analysing, simulating and modelling systems | Yes | Yes |
| 9 | Python, Pydroid | Used for high level programming | Yes | Yes |
| 10 | Stack Overflow | Used for computer programming responses | Yes | |
| 11 | Student Portal | Assignment submission, learning and access to library, paying fees | Yes | |
| 12 | Google | Quick response and information | Yes | |
| 13 | Studio (Android) | Used for unifying environment for building apps for | | Yes |

| | | | | |
|---|---|---|---|---|
| | | various Android devices | | |
| **s/n** | **Tools/Platforms** | **What students do with it** | **Online** | **Offline** |
| 14 | Brackets | Open-source web designing tool | Yes | |

Table 4.1 Engineering tools and tasks carried out on mobile learning.

**4.2.1.1.2.2 Used in-school and out-of-school**

The engineering tasks are either suitable for in-school or out-of-school, it is totally subject to user's convenience of time and where, i.e. spatial consideration. Where they will do a task and the tool they use will determine where and when to embark on it. Respondent #18 said:

> Like other tools, MATLAB, we can use it in school, when we have an assignment or research. They would give us things to design such as a small circuit and run it in school and out of school. We use it more out of school because of the kind of our social environment here. We have been on Workers strike to strike, so I can say that out of school is 70%, then in-school is 30% because it is not more convenient to use it in school.

#### 4.2.1.1.2.3 Tools used in individual and collaborative forms

All students expressed that it is only when the internet is available that they work collaboratively; everyone joins in engineering mathematics solving. From the list in the table, all platforms and tools are usable for their individual and collaborative learning sessions. They said that individual learning or solitary practice occurs more when there is no internet.  Respondent #3 said:

> we spent more time using it at home to work. And we will later work in group, through Google document. Yes, we use it, and everyone brings out what he learned and share. If it is a group work, then we carry it out online.

#### 4.2.1.1.2.4 Categorised tasks according to mobile device specifications

All the students described their use of various mobile devices predominantly mobile phones to do a series of engineering tasks and they stated that an engineering task may require a certain mobile device's specification or features in order to run on that device. According to the students, there are soft tasks that do not require devices with high processor ability whereas the hard tasks that require highly sophisticated mobile devices to run them. For Android device or its equivalent, for instance, devices that are lower than Android ware 8.0 version cannot do most hard tasks, e.g. running engineering analysis on MATLAB, whereas devices lower than Android ware 8.0 version can accomplish soft tasks for them, where an example of soft tasks is opening their textbooks via PDF. Complaints from students who face issues with operation of Apps on devices are sometimes resulting from ignorance of choosing the right device for the right Apps.

In tools' ability to support engineering learning, all the students expressed they have sites that are specifically effective for learning, e.g. YouTube, while some are good for practices, e.g. MATLAB, Simulink, etc. Three basic brands of mobile devices are used by the eighteen participants, and these mobile phones students often used are Android Infinix (8.0 and Above), Samsung and Tecno brands.

The students suggested equivalence of the following device's specifications (adapted from www.giztop.com[10]):

-4G LTE Speed – offering quick internet connection for downloading Apps, streaming content, and easy connection with social media.

-32GB/64GB Internal Memory: that offers large storage space.

-5.5-inch 1920 X 1080 (FHD) Pixels Screen: that offers 16:9 cinema-like screen ratio for viewing of objects and videos.

- Helio X20 Deca Core 2.3GH processor and 4GB of RAM that provide complete performance for running applications, running home screens, flipping through menus and more.

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[10] https://www.giztop.com/leeco-le-s3-x626.html

-21MP rear camera and 8MP front camera, with a dedicated light sensor that enables camera capture with more illumination in dark environments for quality visualisation. And with front-facing 8MP camera.

-3000mAH Battery and Quick charge: Ultra Power Saving mode that sustains the device’ s power longer in between charges, with ability to automatically change the screen colour and shut down all unnecessary features to reduce power consumption.

-Access to Google Play/iTunes: Able to browse and download Apps, books, programmes.

In summary, the findings showed that engineering students’ adoption of mobile learning will be determined by a series of factors including the range of tools or platform. This finding concurs with Bidin and Ziden (2013, p. 725) and Thomas et al. (2013) that stated that technical background features are constructs to students’ adoption of mobile learning.

**4.2.1.1.3 Usability**

Two fundamental sub-themes that emerged here are appropriateness of use and task concept.

**4.2.1.1.3.1 Appropriateness of use**

Two major signifiers explain how their mobile learning is finding appropriation into amelioration of the issues of social changes, e.g. continuing their education during a crisis - last resort during nationwide lockdown, university strikes, etc. These are; Adoption purpose and Frequency of use.

#### 4.2.1.1.3.1.1 Adoption purpose

There are two sub-themes that could explain their kinds of purpose of adoption, namely, technical, and non-technical.

Technical purpose fits into emergent needs of laboratory tools. And these are lists of purposes filtered from the analysis:

Used on the web to study, find information, learn tutorials, find solutions, download textbooks, read texts, file conversions, submit assignments, doing homework, emailing, and storing datasheets.

Uses Apps to do electrical designs, simulations, engineering programming, front-end programming, construction web places with the HTML, CSS and JavaScript Practising on MATLAB and doing C++ programming. Finding values of discrete electronic components, e.g. checking on resistors, transistors, diodes, integrated circuits, and other components. Drawing plans, orthogonal projection, engineering schematic designs. Taking courses online. Making class discussion, posting questions, class lesson and group projects. Simulating, examining, calculating, mapping, verifying for circuit and practice. Designing engineering structure.

Non-technical purpose fits into paying school fees via student portals, exchanging SMS with colleagues, friending on social media such as

Facebook, and YouTube to meet educational friends, view free lessons respectively, follow-up campus news and routines from portal.

#### 4.2.1.1.3.1.2 Frequency of use

The students unanimously expressed that some sites and Apps are more visited than others. Sixty percent of the participants said they use mobile Apps as often as they use social media, websites, and toolbox sites. No one spends equal time on each of the platforms, and thirty-three percent spend more time on social media than elsewhere. They can use all in every kind of environment, but mostly in conducive places, e.g. the social media. Locations where students drop off their ideas, questions, or complicated thoughts requiring a teacher's attention or where they receive attention quickly. They use it more in school because they conserve their personal internet subscription and use the university's internet. They frequent the easy sites such as student's portal, educational websites, and social media.

In summary, what the students know or want to do and the understanding of why they appropriate it in use contribute to determining where and when the students use mobile learning. This finding is underpinned by Huan, Li, Aydeniz, and Wyatt (2015) who state that students' understanding of learning tasks drives them to using mobile learning.

#### 4.2.1.1.3.2 Task concept

Three signifiers explain how tasks influence their mobile learning's time and place. These are; Nature of task, Task hierarchy, and Shortest path or cost.

#### 4.2.1.1.3.2.1 Nature of task

The students outlined some tasks and describe them as complicated or simple based on completion time of the task they do. Complicated tasks are: solving engineering and mathematical analysis, programming on C++, designing advanced electronic circuits, simulation, solving questions and finding derivatives of engineering formula.

Simple tasks are: Tasks mobile learning is used for that are strictly learning and studying engineering (in school). Undertaking a self-development course by taking Udemy and YouTube. Converting and reading documents through PDF, consulting electronic datasheets to look up components. Designing by self-practice. Doing personal learning. Social media discussion. Checking up results from portals.

#### 4.2.1.1.3.2.2 Task hierarchy

In task hierarchy, the students stated that task relevance or urgency places them to proceed others and they sequenced those tasks on ‘to-do lists’ in order of priority or relevance.

#### 4.2.1.1.3.2.3 Shortest path or cost

The Shortest Path or Cost expresses that task selection is either experiential-induced or cost-effectiveness. According to the students’ views, cost effectiveness considers what facilitates students’ assignments - doing and submission. As a last resort, when there is nothing to use to learn, a mobile tool serves as a soft laboratory with conformity to standards. They arrive at their learning goals early or late when using it but it saves them from idling and supports learning during lockdown and labour union strikes.

Experiential-induced tasks considers how much the students know or previous knowledge as that will influence decisions to explore resources. Respondent #6 said:

> most of the applications I've come across use the internet. For example, the calculator-age is one I have come across in electrical application and I use it for doing some electrical analysis.

In summary, the students expressed that they always take short-cuts and prioritise choosing where and when to perform technical and non-technical tasks. This agrees with Taylor et al.'s (2006) view that the structure of the tasks, and for certain tools being used accounts for students' intellectual processes. And Gan et al. (2017, p. 849), evinced that task structure influences choice of where and when students adopt mobile technologies.

### 4.2.2 How do students perceive authenticity of practices performed through mobile technologies?

The above question is research question two and its purpose is to investigate how the students perceive authenticity of practices they perform with mobile technologies in learning engineering, to develop a guide to understanding why they perceive it that way and possibly anticipate inherent factors contributing to it. The data were analysed accordingly, and Figure 4.3 shows the emergence of themes and sub-themes starting from the three main themes that express authenticity of learning and these are user attributes, technical influence, and social effect. Every sub-theme is contributing meaning to the theme it relates to as shown in Figure 4.3. Details of every theme and sub-theme as shown in Figure 4.3 are covered in the following sections and sub-sections sequentially.

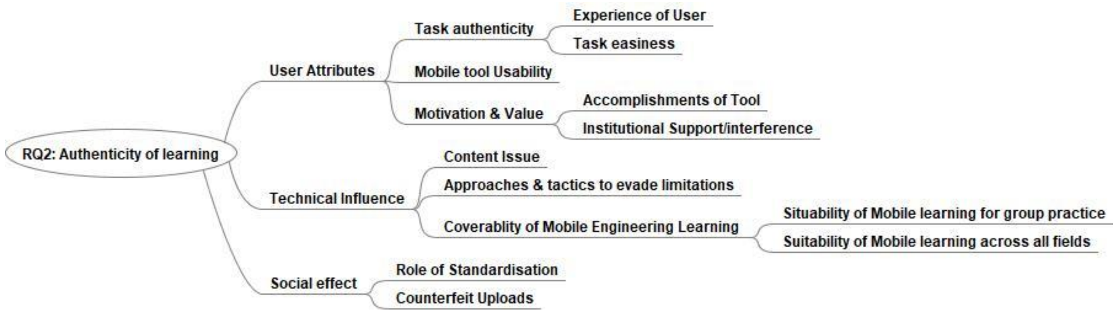



Figure 4.3 Thematic Map Two

During the coding and analysis, three broad themes emerged, and these are:

User Attributes, Technical Influence, and Social Effect.

#### 4.2.2.1 User attributes

All the student expressed that the resultant input to the practice a student does to make it real and authentic considers several key points. This is supported by three sub-themes that were filtered through analysis, namely: Task Authenticity, Mobile Tool Usability, Motivation and Value.

##### 4.2.2.1.1 Task authenticity

According to the theme that came out of the analysis, the authenticity of practices, activities, and tasks they do depend on the student doing the activity and the task she or he does. This is supported by two signifiers namely Experience of User, and Tasks' Easiness.

**4.2.2.1.1.1 Experience of user**

The knowledge level of the user, exposure the student has about the excellent use of digital tools, will put the student in a position to make the real outcome. Such knowledge is programming knowledge, of which an experienced student can avoid the stress of writing long programming codes. If the right step to reach the kernel is known, the student can login and accomplish a task quicker.

Respondent #6, without huge experience said:

> In simulations and testing, there are some areas that I don't understand. When I get that kind of situation, yeah, I don't really know what to do in that situation, so I look for people to learn from them.

Another respondent #12, with experience said:

> There are those that there are harder, they require initial knowledge, like my initial knowledge, adding that to it definitely builds my experience. I need to learn more about them before I can use the hard software.

**4.2.2.1.1.2 Tasks' easiness**

The students revealed that there are two categories of tasks they encounter, the easy and hard ones. The nature of the complicatedness of task determines the length of use and when the true outcome of a task is realised. A student's misstep of procedure during a practice using highly complicated tools such as Apps may amount to not arriving at real outcomes. And some tasks are not stressful but with basic web knowledge the complication is averted.

#### 4.2.2.1.2 Mobile tool usability

The students put this into two aspects, firstly, the mobile device in which an application is running and secondly, the application itself. Both the application and device comprise the mobile tool they refer to. When procedures are followed from job manuals to finalise a job, the students revealed that using the mobile technologies to do tasks, by following the demonstrations of a video manual, are not always authentic. Actions on the mobile tools such as command, do not always comply with real-world practice. Sixty percent of them believed that steps or commands put on the mobile tools always comply with manual procedures, twenty-two percentage were undecided, and close to seventeen percent opined that it does not always comply. Students expressed their views to say why. Respondent #1 said:

> Sometimes I run into errors, but with experience and debugging I resolve it. That's why I used "Stack-overflow[11]" for, once I run in to the

[11] https://stackoverflow.com/

> problem like simulation not complying, I just copy it and paste on the platform, then within a couple of hours, you get solutions.

More students hinted video as the best media option that drive learning deeply and faster. It is stated that mobile learning is easier to understand using the video and easy to use when students are on the move (Suresh & Hemabala, 2013, p.1179).

#### 4.2.2.1.3 Motivation and value

Students expressed they are driven to performance by some factors and that will account to how committed they are to realise an authentic project. This is supported by two signifiers, namely, Accomplishments of several tools, and Institutional support/interference.

##### 4.2.2.1.3.1 Accomplishments of several tools

Doing personal learning was the point that helped some students to, through personal encounter, as sourcing learning through mobile because other sources failed them, develop interest to continuous use of mobile learning. They said they usually do “try and error”, during practice, and get encouraged after seeing some jobs accomplished. They got their self-motivation through it. A larger number of students were motivated by evidence of what they see mobile tools can do and have done. They got exposed through demonstrative teaching, workshops, seminars, research publications, and students’ industrial workplace. This category also comprises of those who have a big value derived from mobile learning. Respondent #18 said:

> I got motivated by the things one can do in mobile device. I can do so many things using the mobile tools.

#### 4.2.2.1.3.2 Institutional support/interference

Demotivation is when they had no support from either the school or teachers. The students unanimously rejected that any school policy should prohibit the use of mobile devices in the school or classroom. One hundred percent of the participants expressed the relevance of mobile technologies to their education. They also stated that the school authority has no support yet for mobile learning.

In summary, the students' user attributes are influential in the situatedness and contextualisation of mobile learning. This was highlighted by Jiang et al. (2018), Schuster (2014), and Schuster et al. (2016), that student learning behaviours and general habits towards related technologies effectuate mobile learning adoption.

#### 4.2.2.2 Technical influence

The students revealed that technicalities associated with mobile learning affect their rate of familiarisation with the tools of learning. Getting familiarised quickly depends on how complicated the technical attributes are. The analysis showed how their jobs relate to real-world engineering practice, what they learn on mobile tools, done and tested to be real in practice.  In investigating how real their practices are with respect to real-world engineering practice, fifty percent accounted that all has been real, twenty-eight percent expressed that authenticity depends on the user and the kind of tasks being done. And twenty-one percent did not make a conclusion and one percent objected that not every task is real in practice. Respondent #14 said:

> Since I can use my mobile device anywhere. Flexibilities is not a challenge. Challenges to me is if the mobile device is not able to run some software and it is compatibility issue.

Technical Influence is supported by three sub-themes, namely; Content Issue, Approaches/Tactics used to Evade Limitations, and Coverability of Mobile Engineering Learning.

#### 4.2.2.2.1 Content issue

Students revealed the impact of contents by the format in which it comes, either as texts, video, graphics or a combination of any of them. Understanding of a practice, especially in the area of practical engineering, they watch the procedures through video and repeat what they see by doing it practically. They said most video-followed practices are easy to accomplish and most scripted procedures are not always easy to accomplish to get perfect results. On the contrary, video streaming sucks voltage more than surfing text scripts. Respondent #6 said:

> The one that consumes battery's voltage most is streaming videos online. But when sharing files and resources with students and studying text files doesn't consume voltage as video. Now, when you look at both those to use to perform tests, the graphics and video will

> engage you with more knowledge, and you learn easily. Video makes learning better, but the disadvantage is that it's consuming a lot of voltage on mobile device.

In summary, improving the contents plays a huge role in placing real capture of practices and enables students to replicate the same easily and derive an understanding. This was equally supported by Dorado et al. (2016), Gezgin et al. (2018, p.12), that say improving the course contents includes design and development of mobile applications that will provide students with mobile learning opportunities.

**4.2.2.2.2 Approaches and tactics used to evade challenges**

There are several tactics the students enumerated that they used to evade the fundamental challenges of mobile learning in their vicinity, to conveniently use them to practice and learn. The students expressed that the presence of challenges will determine the tasks' authenticity. Sixty-one percent identified some challenges even though they proved the challenges are surmountable. Thirty-nine percent stated there are no challenges. This an example of an approach they adopt to wade off the challenges; Respondent #13 said:

> Yes, there are challenges. Because there are some Applications that require frequent updates for the device but for here the major issue we have here is actually network issue, our networks in part of the world are very poor, sometimes we have to look for Wi Fi to connect before you can run your almost like everything. So, I download what I need and use it offline.

#### 4.2.2.2.3 Coverability of mobile engineering learning

There were two signifiers that give meaning to this, and these are, Suitability of Mobile Learning across Fields, and Suitability of Mobile Learning for Group Practice. These two are specifically pointing at breadth or coverage and were evident in the collections from interviews and my diary.

##### 4.2.2.2.3.1 Suitability of mobile learning across fields

There was a contention amongst students about how fit mobile learning can go into the areas of engineering. There are divergent views from respondents. Seventy-eight percent opined that it can be adopted for all, eleven percent were not sure, and eleven percent said that it is not implementable.
Respondent #9 said:

> In school, it is very suitable for all the engineering courses. Mobile learning is suitable because of insufficient Lab equipment that is used for practice.

However, since more students expressed that mobile learning is suitable for all aspects of electrical and electronics engineering, this concurs with Schuster (2014, p.461) who found in a study that mobile Apps provide a general use without being subject-specific. It states that even the sciences use engineering mobile Apps to solve their problems.

#### 4.2.2.2.3.2 Suitability of mobile learning for group practice

The students’ views were investigated on the possibility of using mobile learning for group practical. They responded that apart from virtual world tools, that it is not perfectly possible to adopt it for group practice. They all unanimously said that most practices are done individually, and they later converge to brainstorm over their private practices. The only group work they mention is possible is the treatment of theoretical points.

In summary, the technical influence, by extension the use of tactics and nature of content, has huge impact on the authenticity of the students’ practices and learning. This is in line with De La Iglesia et al. (2015) who point out the challenges of engineering mobile learning applications for collaborative mobile learning scenarios. Also, Ma et al. (2016) highlight how developing a complementary tool using mobile learning concepts and technologies enhances students’ interests.

### 4.2.2.3 Social effects

The analysis revealed the lag of professionalism and standard of local practice against foreign standards that appear with contents. This is supported by two sub-themes, namely, Role of Standardisation and Counterfeit Uploads.

#### 4.2.2.3.1 Role of standardisation

They expressed the role standards play in translation to the real-world of practice from mobile practice. They said if the standards on mobile learning tasks and that of the real-world are the same, authenticity is possible. Standards vary according to countries; if they are followed then the real practice will be same as mobile practice. However, they cannot do all they do in real practice on the mobile device. They expressed that non-compliance of some practical results is due to standards variation. Standards need to match on the mobile interface and in real practice. Apart from practice on those two worlds - mobile and real-world - the standards must also reflect on the mobile tool being used, a total compliance to units of measurement, value and quantities are all effecting the project result; the way a mobile side truncates figures or approximates results could cause disastrous changes and distort results from analysis. Respondent #4 said:

> Yes, what we do in mobile tools translates to the real practice. The difference is not much. Most things are closely related. If the standard for the mobile practice or experiment is set to be same as the one in real practice, the result will conform to the real-world practice.

Therefore, it is important to translate standards so that mobile learning projects can be authentic. Lipovszki and Molnar (2007, p.7) hinted at the role standards play in mobile engineering learning.

#### 4.2.2.3.2 Counterfeit uploads

Students revealed that some uploads to websites especially YouTube are unverified sources and unverified practices as many of the procedures when followed failed to reach an authentic result. All the participants unanimously agreed that counterfeited uploads exist in various sites. Respondent #8 said:

> On the aspect of YouTube, this is the place where some practices we adopt do not translate to the real-life practice because of wrong or unverified procedures. Yeah, it is based on what they are putting, they are not authentic.

In summary, the reality of practice in the real-world understanding of engineering from the students' practices, activities and learning on their mobile tools depends on the standardisation and scrutiny of web resources that students use. However, Hosny (2007, p.973) hints that standards have been troubling engineering education across countries due to competing web languages and network transmission standards. Students decried the varying standards of contents passed on the various platforms of learning such as units and codes appearing in contents delivered.

### 4.2.3 How do students create their own learning by customising activities?

The above question is research question three and it was designed to get information about the students' perceptions about their customisation of tools, agencies or how it is customised and why it is customised in that way.

Learning through practice is an essential part of engineering education, how do students create their own learning by customising activities? This research investigated how they personalised mobile tools and learning in engineering. The data were analysed accordingly and Figure 4.4 shows the emergence of themes and sub-themes starting from the four main themes that express how the students are personalising learning and these are: Familiarisation and Assistance; What and How the Students Attain Personalisation; Adaptabilities and Adaptive features; and Transitions and Perceptions. Every sub-theme is contributing meaning to the theme it relates to as shown in Figure 4.4. Details of every theme and sub-theme as shown in Figure 4.4 are covered in the following sections and sub-sections sequentially.

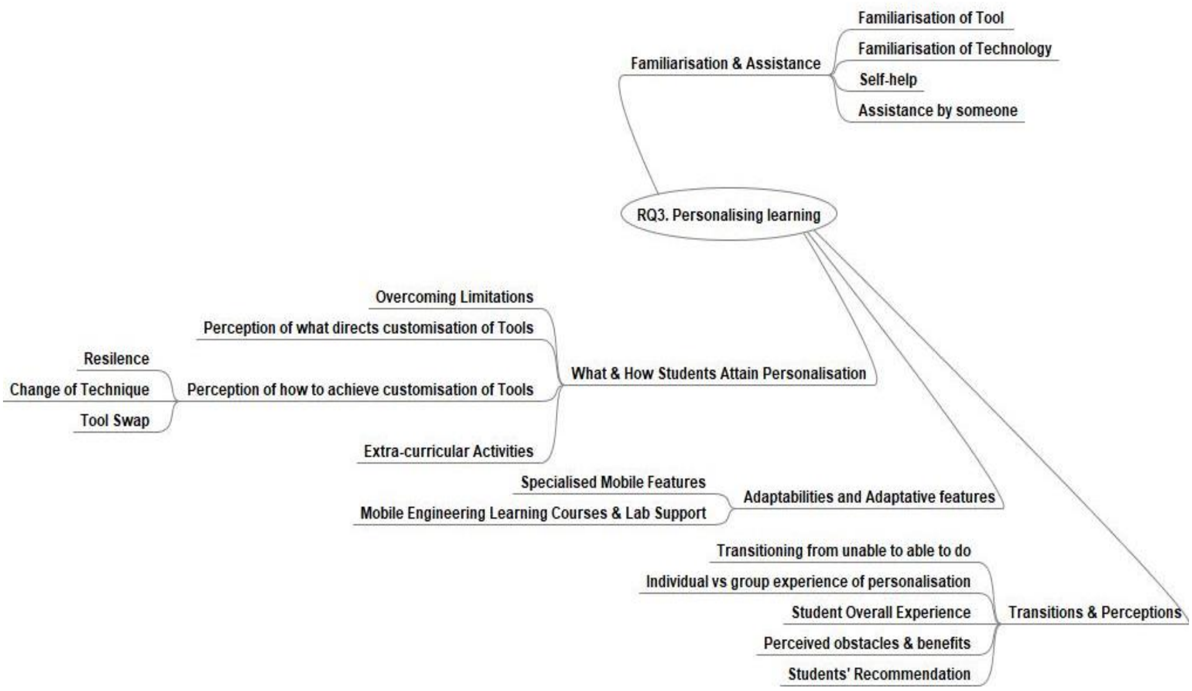



Figure 4.4 Thematic Map Three

#### 4.2.3.1 Familiarisation and assistance

The students expressed two broad views of the process of getting familiar with mobile learning, seventy-eight percent said that initial training is definitely required to use most of the important platforms used in engineering education for practice but not necessarily required for the platforms for reading or viewing. Twenty-two percent stated that there is no special training required to use the mobile platforms.

Out of this, there are four broad themes that emerged after analysis: (a) Familiarisation with the tool, (b) Familiarisation with the technology, (c) Self-help, and (d) Assistance from others.

##### 4.2.3.1.1 Familiarisation with the tool

The students expressed their understanding of the mobile device they own such as tablet, or smartphone being used for learning and the platforms such as Apps, websites, etc. They have owned their devices for a long time, and they said it contributed to customising some effects and identifying agencies and use of them and knowing conditions under which they can be used. Agencies are what offers range of choices to them, such as a connect from previous knowledge to a new knowledge of how to do a thing. Having a perfect knowledge about the two are what the students say are relevant in personalising mobile learning. Respondent #1 said:

> You must understand the device properly. I think most people in my age group are familiar with the mobile device. So, we are, most people

are, not every everybody. Most students are familiar with what they use.

In summary, the familiarisation with the mobile device the students use to learn plays a huge role in how much they can customise most features and enjoy their practice and learning. This concurs with Marin and Mohan (2009, p.33) and Simonova et al. (2015) that students' familiarisation and ownership of the device are highly important even in selecting and improving ways of impacting knowledge in students.

#### 4.2.3.1.2 Familiarisation with the technology

The students expressed that the technology of using the mobile tool (device and platform) in solving, treating, inquiring, investigating, designing, or troubleshooting an engineering problem is an important key. The process of application of principles of laboratory use and knowing how to bring it into the mobile phase so that real results are attained is challenging to them when they use some of the mobile Apps. For instance, a student knows how to design a rectifier circuit in a physical laboratory, knows how to operate a smartphone but needs training to know how to use both to achieve a purpose using the appropriate platforms. And the selected platforms pose extra requirements of learning how to use the platforms especially mobile Apps.

#### 4.2.3.1.3 Self-help

This theme surfaced, and it is noteworthy because the students mentioned that there are some tasks where they need no assistance. Platforms do not

make mobile learning tough, but the contents and structure can. Some tasks appear on various platforms, varying in toughness or simplicity. Tough or easy mathematical analysis can appear on easy-to-use platforms such as websites, social media, or portals while it can also appear on tough-to-use platforms. All the students agreed that personal efforts see them through when the content appearing in an easy-to-use website is easy to understand and use.
Respondent #6 said:

> In some cases, I have been directed by someone to do some tasks by our teachers. And in most times, I do it on my own. When it is tough, I go online very well to seek the solution.

#### 4.2.3.1.4 Assistance from others

Students require assistance for tough mobile Apps especially. They all express they seek help from an online tutor they secure from social media - YouTube and Facebook or classmates who are familiar with the procedures of the problem-solving and the technology of that application in question. None of the students have used the help resources of the Application owners due to cost and time. Respondent #7 said:

> The online sources from social media and YouTube are the major places that give us deeper understanding on the topic we are working on. For me, by going to the YouTube, I learned the application of the use of the AutoCAD. And it really helped me in the drawing and designing. For designing, I have a friend, he’s in civil engineering and I connect with him through that medium to learn.

In summary, the assistance the mobile learners require alters or enhances the process of personalising learning and the tools used for learning. This implies that tutoring systems can help students advance their knowledge level, achieve their learning outcomes and have a pleasant and effective learning experience (Troussas et al., 2020, p. 2). Tutoring systems are assistive tools for learners using mobile tools to improve customisation of their tool and learning.

#### 4.2.3.2 What and how the students attain personalisation

The students expressed various approaches to reach their practice goals. There were four sub-themes that emerged to explain how they attain personalisation: Overcoming limitations, Perception of what directs customisation of tools, Perception of how their customisation of tools are achieved, and Extra-curricular activities.

##### 4.2.3.2.1 Overcoming limitations

How the students attain personalisation is by addressing or handling the limitations that are associated with mobile devices they use. They mentioned four fundamental limitations of their mobile devices, with reference to mobile phones, and one limitation is from the user and others are small screen size, low power supply, control of content, distraction, and inadequate knowledge..

The student tends to either devise schemes to avoid limitations so that they can do their design tasks on the mobile tools or they become accustomed to the device the way it is.  Respondent #8 said:

> … there is no outstanding obstacle, because if a student has the theoretical knowledge of what he wants to do on the applications, it removes the major obstacle of the way. And the various tasks we use them for are simulating, designing, or get some resources such as textbooks.

#### 4.2.3.2.1.1 Limitations of using mobile devices/tools

The following were listed in the interviews:

**(I) Screen size**: The screen size limitation is described by all students as something they get used to after several months of use. They became adapted to the screen size. They usually rotate the screen at 90 degrees (vertical to horizontal view) to view large images. For instance, the small screen size limits visualisation of contents, and the students address that by doing a screen rotation as shown in Figure 4.5 and magnifying the view of content with a magnifying lens.

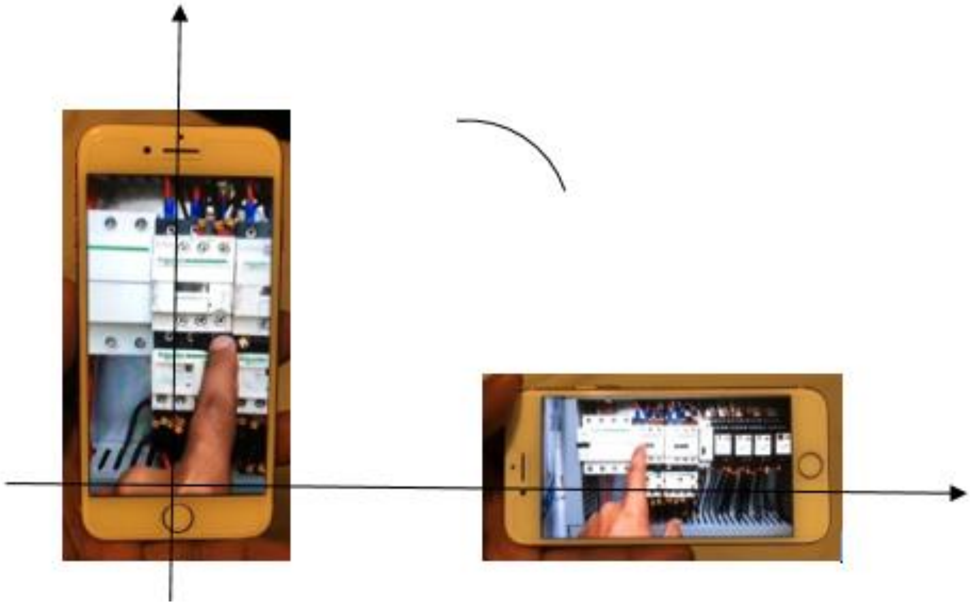


Figure 4.5 Student's 90º (degrees) rotation of device to improve visualisation in order to evade small screen limitation (source: own photo used to describe the student's approach to activity).

**(ii) Low power:** The power supply is minimally small size and voltage magnitude. That means that all the students use a power-bank as an extra power pack which they carry in case their mobile device runs out of voltage or power. The students said that a good device that suits their use based the under-developed situation of the country is at least a device above 400 mAH of battery capacity. Students charge their device while they are on the move; they plan how long the voltage can carry their task before resuming a task. Most students said that at full charge of voltage, a mobile smartphone lasts 10 hours without internet use, working with offline Apps, and with internet use, it lasts for about 5 hours.

**(iii) Control of content:** A major concern the students complained about came from mobile Apps. Only twenty-two percent decried content type as a major limitation. Others see this as no major hindrance to adoption of mobile Apps unlike Toolbox. About content type, it is not easy to familiarise quickly with most engineering mobile Apps because of the many task's procedures involved, though familiarisation with the tool and the task minimizes the difficulty. The appearances of contents sometime are not fully displayed, and some menu lists would be hidden. Also, to attain adequate content control, students use their mobile devices to cast the content images so that they can manipulate the content as shown in Figure 4.6, where a mobile App is used to control a small size surveillance robotic rover after making a wireless connection with the rover.

A sample of a task performed by a student is shown in Figure 4.6.

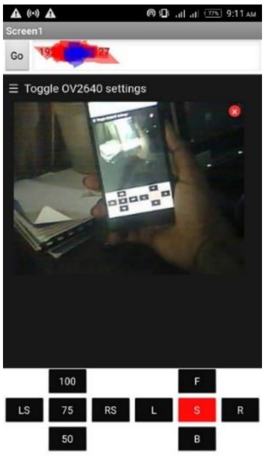



Figure 4.6 The mobile App that can connect a small size surveillance robotic rover via Wi-Fi, control the rover and stream the camera in the rover (source: respondent #18, collected with student's permission).

**(iv) Distractions:** They unanimously expressed that there may seem to be a distraction, but it makes no sense to them. They do not admit that distraction is associated with mobile learning when any student is seriously focused on the task in hand.

**(v) Inadequate knowledge:** Not having full knowledge of doing so many engineering tasks in every mobile App is a limitation to many of the students as they hinted.

**(vi) Choice of tools** (some students use inferior phones due to low-income, for high capacity Apps): all the students are using mobile phones as their major mobile device. Only less than one percent own a tablet PC and alternate it with the mobile phone. All the mobile devices they use are mobile smartphones. They expressed that their devices are incompatible with some mobile Apps such as MATLAB, Python, and AutoCAD.

**4.2.3.2.1.2 Approaches the students adopted to avoid limitations**

The students steadily mentioned these key limitations (see Table 4.2) and described how they handle each one and successfully attain their learning objective.

| s/n | Location of Limitation | Approaches that worked for the students |
|---|---|---|
| 1. | By Screen size | Connect to a large plasma television using a compatible interface cable or wireless<br><br>Or rotate the screen once at 90º degree, to a landscape view |

| s/n | Location of Limitation | Approaches that worked for the students |
|---|---|---|
| 2. | By Low-power supply | Move along with extra power-bank; Use or view less video-related programs |
| 3. | By Content complications | Consult experts or check online help |
| 4. | By Distractions | Concede no distraction; Stay focused; Study in a conducive place; Verify location before settling there for study; Use the university library; Self-discipline |

Table 4.2 Limitations and students' approaches to avoid them

In summary, the creativity of the students using mobile tools to learn by ignoring or minimise limitations explains the efficacy of their personalisation competency. This was supported by Hwang (2014) that smart learning evolves through responsiveness and adaptation to changing learning traditions and activities. Also, Edein et al. (2015, p.20) state some of the limitations enumerated here as some constraints to the students' effort to customise mobile learning.

**4.2.3.2.2 Perception of what directs personalisation of tools**

What directs personalisation of tools are:

**(I) Easy content to use:** Easiness of use in doing a task is dependent on an individual's experience and how the styles of every page of the platform are arranged to promote usability. Studying from YouTube or Facebook and reading from websites are easier because the pages are similar, while working with Apps is harder because as the students swipe further to do intricate problem-solving, the complexity of mathematical formulae and page changes add confusion and then there is a need for gradual steps of identifying each stage of the task process. The kind of task will determine if a tool is suitable or not. Analytical tasks differ from designing tasks and the students expressed that both require different mobile Apps for each.

**(II) Most usable:** When a tool is easy-to-use and can solve their learning needs, students adopt it regularly. The students expressed that they go for Free and Open-Source Software (FOSS) applications most of the times as those do not require payment. A student's level of experience and knowledge will determine whether a mobile tool will be easy and usable. And what also matters is the student's area of specialisation in engineering, e.g. those in computer engineering specialisation have high passion for programming. Passion drives them to continue doing programming always with their devices and they get used to it. Also, they state that the reason social media leads as their most visited platform is that there are many people who can offer them assistance when they are stuck in a task or assignment.

**(III) Learner-friendly:** The students articulated that those platforms they used on mobile devices have decent user interface design, familiar screen pages, frictionless navigation while they scroll or swipe, and all are happening in a very responsive manner.

**(IV) Most suitable:** Mobile learning is very suitable for the students' kind of society because everyone can afford a mobile phone. All the students expressed that offline Apps are most appropriate in their environment because students from low-income level support hardly have funds to subscribe regularly for internet provision as their university internet is not reliable.

#### 4.2.3.2.3 Perception of how their customisation of tools are achieved

There were three signifiers that explain this, and these are Resilience, Change of Technique, and Tool Swap.

##### 4.2.3.2.3.1 Resilience

The entire students expressed that they do not have any other alternatives to solving their learning needs when completing assignments, studying for examinations, revising laboratory practices at home, etc., except by using mobile learning. And they persevere to keep using it despite limitations of their devices and the challenges posed by their environment. Continuous trial and resilience get the students through those tough experiences. Respondent #1 said:

> The point is that at first it might be strange to you but once you do it, the first time, the second time, the third time, you keep doing it and it then becomes part of you don't even need to do it the same way anymore.

#### 4.2.3.2.3.2 Change of technique

They alter the approaches that they used in the beginning and try different methods to break through the limitations. The students that belong to this category said this occurs when they could not find help from anywhere, while working on their tasks.

#### 4.2.3.2.3.3 Tool swap

They described their swap of tools especially the mobile Apps between tasks when they cannot proceed with a current App. For instance, a student switched to using Python to plot graphs when doing the same task that with other software refused to work in the mobile Spreadsheet.

#### 4.2.3.2.4 Extra-curricular activities

This sub-theme emerged from the data analysis separately, even though they are not engineering practice, because of its critical contribution to the students' personalisation efficacy. The students perceived excellence in non-engineering activities that in a way contribute to developing the students' ability to customise features of the mobile device they use for learning. They expressed that as they use their mobile device to do non-engineering related tasks they contribute to easy navigation on the menu of their device's screen and this reduces the time taken to identify desktop icons and buttons through constant use of the same mobile device in both non-engineering and engineering tasks. Some of the non-engineering tasks enumerated by the students are: reading non-fictions, documenting, storing and managing personal files, fashion designing, piano practicing, listening to music and news, advertising, doing presentations, business marketing, and chatting on social media.

In summary, the students’ core learning milieu and their part-time activities may or may not be related or work together. However, students expressed the role of part-time activities that support their capabilities in personalising their tools, tasks, device and learning with technology. From their viewpoints, it is either that extra-curricular practices belong to:

(i) Contributions of non-engineering to personalising engineering activities.

(ii) Disruption of learning process by non-engineering activities.

In summary, the non-core engineering activities do contribute in developing the student’s knowledge of mobile features and usage. This agrees with Chakravarthy and Sunitha's (2020) suggestion that the use of mobile Apps practicing a non-engineering practice, i.e. the comprehension reading, enhances the chance of becoming an expertise.

#### 4.2.3.3 Students’ adaptabilities and adaptive features

There were two sub-themes that emerged from this topic; and these are Specialised Mobile Features, and Mobile Engineering Learning Course and Laboratories Support.

#### 4.2.3.3.1 Specialised mobile features

The Specialised Mobile Features are the features that all the students said that they customised, and that are important to them. These are what have fitted into the way they learn to meet their individual needs and practice requirements. These are: (i) Processing speed, (ii) Touch-screen, (iii) Storage size, (iv) Memory, (v) User Help Menu, (vi) Network detection and connectivity, (vii) Battery capacity, (viii) Accessories - camera, printing service, measuring, rotation and gyroscopic use, etc., (ix) Control and navigation, (x) Regular updates of software, (xi) System support from the manufacturer.

#### 4.2.3.3.2 Mobile engineering learning course and laboratories support

A list of expressions by students showed what they can do, and what was used and not used in their engineering education for courses and in supporting laboratory practices.

In summary, the technical features, support and adaptabilities or adaptive approaches of the students that contribute to their ability to locate agents of their mobile adoption and customise their mobile learning and its technologies. This concurs with Kinshuk et al. (2009) that states personalisation can occur via two adaptive approaches, one by adapting to the student and the other by adapting to the context of the student's surroundings. By putting students' adaptive characteristics, students are provided with learning resources, experiences, and activities that go with their respective learning needs and requirements. All discussed above contribute to the students' ability to personalise the tools used for learning. It agrees with the fact that the functionality of personal devices and perception of support from the material or resources providers affects the students' satisfaction and decision to use mobile learning (Li et al., 2013, p.476).

#### 4.2.3.4 Transitions and perceptions

There were three themes that emerged from this and these are: Transitions, Individual and group experience of personalisation, and Student overall experience.

##### 4.2.3.4.1 Transitions

The students described their learning journey in developing knowledge of using platforms, especially what they consider to be the toughest mobile Apps. The SIWES programme was an opportunity for cementing their abilities in working practices carried out with mobile tools.

###### 4.2.3.4.1.1 Transitioning from unable to do to able to do

The time frame to move from unskilled to expertise in customisation ability was that the students could not do engineering tasks with platforms especially mobile Apps, MATLAB, Simulink and AutoCAD during their first and second year. Only twenty-two percent stated they developed knowledge of working with those three major mobile Apps at the end of their second year in the university while the rest developed their knowledge in their fourth year. That implies that the time frame from unable to use to able to use is between 100 to 300 levels of academic study.

#### 4.2.3.4.1.2 Transitioning from able to do it to becoming an expert

This is the difference between when the students developed knowledge of using major platforms they required for study to the time when they were fully able to do the tasks required. Only eleven percent were fully able to do all required engineering tasks.

*Some of what they could not do before and what they did during the transition to make the difference:*

-Managing files using the mobile device especially textbook was seen as tough by a student. By himself, he devised another way to edit and share files by chunking the file size.

- A student had difficulty finding answers to questions on the App he uses. He asked his peers as he could not find answers on the device's help menu.

-A student could design with a mobile App but his designed circuits do not work. An approach that saved him was designing in mobile App first and test. He then followed the sequence and designed in real life what later worked.

-A student could not use the spreadsheets to do data handling before. He was taught by his colleague to analyse formula and calculate on a spreadsheet.

-A student could not do cloud computing before. He was trained by YouTube online tutors, and he could do it now.

In summary, the transitioning pattern is evident in the student's use of mobile tools as they improve their smart learning ways. This agrees with Zhu et al.

(2016), that students employ devices to access digital resources to immerse in both personalised and seamless learning through changing learning traditions.

#### 4.2.3.4.2 Individual versus group experience of personalisation

Sixty-seven percent of all the participants, i.e., students, indicated they have both individual and group experience when it comes to customising tools, which they use individually to achieve their common purpose. Thirty-three percent have not got experience of personalisation when working in a group. They said they gather, each one with his own device, and use them to collaborate by sharing ideas. They said the way each person takes while using individual devices may differ because their device features are distinct.

According to a student's experience, individual approaches differ because they are all using different devices and have distinct ideas.  If all students work together on a project and are following the same procedures with similar devices, the experiences may or may not be the same due to personal ideas. They expressed that working groups will have the same results as individuals in some respects.  Working in groups saves time even though creating engagement is denied because of the asynchronous nature of learning. The students expressed that collaborative learning should be on theoretical areas. They get more output when they worked in groups.  Different views bias customisation of process and procedure of an activity due to the different level of exposure or knowledge of individuals and familiarisation levels of devices by every user. Collective knowledge is built from the individual influences that differ. Sometimes, a group activity's result is not same as an individual's because of distinct device exposure, even though it is one similar task with one streamlined procedure. They do not do group practical on mobile devices and tools, but they specifically do individual practical plus learning, and then gather to share ideas.

In summary, the difference between individualised perspective and personalisation lies in the student's ability to control the device and its related data, and their group perspective becomes their overall experience (Clarke, 2003).

**4.2.3.4.3 Student overall experience**

The students expressed their overall reactions, perceived obstacles and benefits and recommendations for further implementation. These are segmented themes that were produced from the analysis and they are codes that emerged from the data. These are:

**4.2.3.4.3.1 Students' overall reactions/experience**

Seventy-eight percent expressed their overall experience and satisfaction levels, and eleven percent did not say their satisfaction level but said that it has improved their engineering education. The highest value as verbally stated by a student as an overall experience is about 95% and the lowest is 80% in using mobile learning. There are more benefits than obstacles; everyone has individual limitations based on mobile device in use, but they always navigate to reach their goal. It boosted their design skill using

AutoCAD. It offers to them a quality teacher-student interactivity – with a useful teacher feedback pathway. Mobile learning replaced the obsolete way of study with only textbooks. It makes study easier and gives them user satisfaction, stress-free and time saving. They all believed that it serves as an alternative laboratory tool. It has improved their programming skills. All the students overall experience is that it is boosting their engineering expertise and knowledge despite limitations of each of their individual mobile devices.

#### 4.2.3.4.4 Perceived obstacles and benefits in personalising tools

All the students unanimously expressed that there are concerns when it comes to personalising their use of mobile tools to learn.

Slow processing and switching between navigations due to RAM size or not using a higher performance phone with large RAM that can carry the program. One major advantage they said is that it is keeping students prepared ahead of class lessons. They anticipated that virtualisation may not be an obstacle if it is introduced in their laboratories, but they said they had not tried it yet.

#### 4.2.3.4.5 Students' recommendations

The following are the major recommendations that were produced from the data: Split pack of large file programs will be helpful with such large programs as AutoCAD and MATLAB, so that it can run speedily on most simple mobile phones the students use. University entrants need orientations on how they can use the mobile devices to do certain tasks and educate them on when or what they should not use them for. Uploads on YouTube must be verified.

Building a small world of all personal activities into a mobile device, i.e. virtualisation, for the engineering students. Break-up of voluminous and hard-to-learn Apps, e.g. MATLAB into stages of uses, with answers to tried tasks. More recommendations are discussed in detail in the next chapter.

In summary, the students' perception of the efficacy of ways they can create their own learning and how it is self-directed by customising engineering practices, mobile features, tasks, are influenced by some factors that lead them, they may or may not struggle with adopting mobile learning. To agree with the finding, Huang (2014) and Li et al. (2013) revealed the students' individual perception and knowledge of use and mobile tools features are liable to personalisation of learning. In the same vein, Middleton (2018) summarised that students create self-directed, learner-centred empowered smart learning, with mobile tools.

### 4.2.4 How do students collaborate on social media for learning purposes?

The above question is research question four and it was designed to investigate the interactivity and collaborative learning pattern that travailed in two social media sites that the fourth-year students used for learning a power engineering course. Why students do not use interactive or collaborative media more often still needs to be investigated on a deeper level (Schuster, 2014, p.462). For that, questioning the students, i.e. participants on the mobile social network, followed the social network analysis.

The Facebook and the class course blog were analysed. The connection of this approach to previous qualitative processes is to follow up with outcomes from the social media platform. Students had unanimously agreed that it is the most frequently used platform for learning and the easiest among other platforms they use. The two sites were selected because that was where actions took place as those sites are owned by them.

A follow-up qualitative approach seeks to investigate why levels of participation of every student vary on those two social network sites.

Codes were initially used to sort the data from interviews and observations from the sites. The codes included motivations and demoralisations that encumbered students' interactivity during the learning process. Data from these codes were subsequently analysed for significant statements and meaningful themes.

#### 4.2.4.1 Building a dataset - the blog profiles and data

A six-week collection of learning in a course was used for this investigation. I chose to use a small size out of the entire semester period because of in-class activities resumed after the university's non-teaching staffers' strike was over. The mobile learning activities were done temporarily during the over ten-week strike period, and it served the data used in this analysis. Also, using small size of the network is allowed as is better in avoiding errors during network analysis (Saqr, Fors & Nouri, 2018). Data were retrieved manually from the blog and Facebook page by counting, and the blog's statistics are shown in Table 4.3. This shows the magnitude of posts or messages which were returned as feedback to every participant in the class. The details of Table 4.3 were entered as counts of the messages on the SNS, for instance, when the teacher made the first post, titled 'Post 1' in Table 4.3, there are 46 replies from various students between 25th and 30th of August. The SNA filtered and presented only the participants and their interactions. The blog address is *www.ikole-engineering.blogpost.com*[13], and the Facebook group page is *Electrical Power Principle Group*. Both are accessible on the web.

| **Period** | **Post 1** | **Post2** | **Post3** | **Post4** | **Post5** | **Post6** | **Post7** | **Total** |
|---|---|---|---|---|---|---|---|---|
| 25th -30th Aug.2019 | 46 | 20 | 0 | 0 | 0 | 0 | 0 | **66** |
| 31st – 5th Sep. | 7 | 11 | 4 | 0 | 0 | 0 | 0 | **22** |
| 6th-10th Sep | 0 | 1 | 4 | 2 | 0 | 0 | 0 | **7** |
| 11th -16th Sep. | 3 | 2 | 2 | 13 | 5 | 0 | 0 | **25** |
| 17th -21st Sep. | 2 | 4 | 3 | 11 | 9 | 0 | 27 | **56** |

[12] https://ikole-engineering.blogspot.com/

[13] https://ikole-engineering.blogspot.com/

| Period | Post 1 | Post2 | Post3 | Post4 | Post5 | Post6 | Post7 | Total |
|---|---|---|---|---|---|---|---|---|
| 22nd – 27th Sep | 3 | 1 | 1 | 1 | 1 | 34 | 13 | **54** |
| 28th – 3rd Oct | 0 | 0 | 0 | 2 | 0 | 10 | 3 | **15** |

Table 4.3 The students-teacher's posts in a six-week period on the class blog

I used *Gephi* 0.9.2 software to analyse the dataset, and the result has 56 nodes and 132 ties. Nodes are the students who are connected or unconnected to each other and ties are the connections that show their communications (see Table 4.4).

| s/n | Metrics/network descriptive | Values |
|---|---|---|
| 1 | Nodes: | 56 |
| 2 | Ties: | 132 |
| 3 | Diameter: | 2 |
| 4 | Radius: | 1 |
| 5 | Average Path length: | 1.957 |
| 6 | Average Degree: | 2.357 |
| 7 | Average weighted degree: | 17.393 |

| s/n | Metrics/network descriptive | Values |
|---|---|---|
| 8 | Network density: | 0.043 |
| 9 | Eigenvector centrality:<br><br>Number of iterations:<br><br>Sum change: | Undirected,<br><br>100<br><br>3.703 |
| 10 | Average Clustering Coefficient: | 0.784 |
| 11 | Total triangles: | 11 |

Table 4.4 Metrics of Blog`s Interactivity analysed by SNA tool.

Recalling description from section 3.9.5, the values in Table 4.4 are showing the pattern of conversation that happened among the participants in the blog. The interpretation shown is a structure (and its information) that emerged during the communication amongst students and the teacher in the blog. For instance, 11 triangles tell us that when the entire network structure is put into all possible triads, i.e., three participants, that the maximum is 11. A triad is when three individuals have communicated and there exist ties among them (see Borgatti et al., 2013). From the result produced by *Gephi* software in Table 4.4, the diameter of the blog plot is two and the radius, one. The diameter is the lengthiest graph distance between two nodes in the network, that is how far apart are the two farthest nodes. The clustering coefficient shows a small effect. It shows how the participants are embedded in their neighbourhood (i.e., online community such as interactions on a blog). It indicates how well a node is connected. If the online community is fully connected, the clustering coefficient is 1 and a value close to 0 indicates that there are hardly any connections in the community. The clustering coefficient is a measure of the degree or ability of a node's neighbour to cluster together, or form a complete graph, also called a clique (Arif, 2015, p.891; Mislove et al., 2007). The average clustering coefficient is the mean value of individual coefficients (Mimarcel, 2014). The average shows an overall impression of the clustering in the network. Eigenvector centrality is a measure of a node importance in a network based on a node's connections. It is a measure of the influence a node has on a network. If a node is pointed to by many nodes (which also have high eigenvector centrality) then that node will have high eigenvector centrality. The sum change is the difference in total of all the eigen centralities. The number of iterations is how many iterations or cycles that the computation was run by the software. This is undirected in the sense that messages are not directed to anyone but posted for everyone to respond back to the message. This makes the entire plots used to be described as undirected networks. The average path length is the distance between two nodes measured as the number of ties between them; it is a measure of the efficiency of information transfer. The average degree is the average number of ties per node in a graph. The average weighted degree is the average sum of weights of the ties of a node. A triangle implies a set of three nodes, where each node has a relationship to all other nodes (Borgatti et al., 2013).

#### 4.2.4.1.1 Analysis of collaboration of participants from SNA plot of blog and message analysis

The collaborating groups comprise thirteen participants, which constitutes 16.88% of the entire population. Some participants (42 students, i.e. 57.14%) filed a single message to the teacher and others (21 students, 27.27%) did not file at all. The identified grouping using the SNA plot shows the groups of students that collaborated or did a task together. A message that received a feedback is counted as one and only student-teacher interaction does not constitute collaboration.

| Discussant groups | Size of participants (including the teacher) | Members of the group | On-task message + Off-task message that could be an icebreaker | % contribution to participation |
|---|---|---|---|---|
| 1 | 6 | E4, E17, E44, E46, E52, E78 | 11 | 4.30 |
| 2 | 6 | E74, E7, E24, E39, E14, E78 | 6 | 2.34 |
| 3 | 5 | E17, E28, E56, E4, E78 | 10 | 3.91 |
| 4 | 4 | E14, E5, E74, E78 | 7 | 2.73 |

| Discussant groups | Size of participants (including the teacher) | Members of the group | On-task message + Off-task message that could be an icebreaker | % contribution to participation |
|---|---|---|---|---|
| 5 | 3 | E28, E17, E78 | 7 | 2.73 |
| 6 | 3 | E44, E4, E78 | 2 | 0.78 |
| 7 | 3 | E56, E17, E78 | 8 | 3.13 |
| 8 | 3 | E24, E74, E78 | 7 | 2.73 |
| 9 | 3 | E46, E4, E78 | 10 | 3.91 |
| 10 | 3 | E39, E74, E78 | 7 | 2.73 |
| 11 | 3 | E52, E4, E78 | 6 | 2.34 |
| 12 | 3 | E7, E74, E78 | 6 | 2.34 |
| 13 | 3 | E5, E14, E78 | 6 | 2.34 |
| 14 | 2 | E3, E78 | 1 | 0.39 |
| 15 | 2 | E6, E78 | 2 | 0.78 |
| 16 | 2 | E8, E78 | 6 | 2.34 |
| 17 | 2 | E10, E78 | 5 | 1.95 |
| 18 | 2 | E13, E78 | 1 | 0.39 |
| 19 | 2 | E15, E78 | 4 | 1.56 |
| 20 | 2 | E18, E78 | 3 | 1.17 |
| 21 | 2 | E20, E78 | 3 | 1.17 |
| 22 | 2 | E22, E78 | 4 | 1.56 |

| Discussant groups | Size of participants (including the teacher) | Members of the group | On-task message + Off-task message that could be an icebreaker | % contribution to participation |
|---|---|---|---|---|
| 23 | 2 | E23, E78 | 4 | 1.56 |
| 24 | 2 | E26, E78 | 1 | 0.39 |
| 25 | 2 | E27, E78 | 3 | 1.17 |
| 26 | 2 | E29, E78 | 7 | 2.73 |
| 27 | 2 | E32, E78 | 3 | 1.17 |
| 28 | 2 | E33, E78 | 5 | 1.95 |
| 29 | 2 | E34, E78 | 1 | 0.39 |
| 30 | 2 | E35, E78 | 5 | 1.95 |
| 31 | 2 | E40, E78 | 2 | 0.78 |
| 32 | 2 | E41, E78 | 6 | 2.34 |
| 33 | 2 | E42, E78 | 6 | 2.34 |
| 34 | 2 | E43, E78 | 7 | 2.73 |
| 35 | 2 | E45, E78 | 8 | 3.13 |
| 36 | 2 | E50, E78 | 8 | 3.13 |
| 37 | 2 | E51, E78 | 1 | 0.39 |
| 38 | 2 | E53, E78 | 8 | 3.13 |
| 39 | 2 | E55, E78 | 1 | 0.39 |
| 40 | 2 | E57, E78 | 5 | 1.95 |

| Discussant groups | Size of participants (including the teacher) | Members of the group | On-task message + Off-task message that could be an icebreaker | % contribution to participation |
|---|---|---|---|---|
| 41 | 2 | E58, E78 | 1 | 0.39 |
| 42 | 2 | E61, E78 | 5 | 1.95 |
| 43 | 2 | E62, E78 | 2 | 0.78 |
| 44 | 2 | E64, E78 | 4 | 1.56 |
| 45 | 2 | E65, E78 | 5 | 1.95 |
| 46 | 2 | E66, E78 | 5 | 1.95 |
| 47 | 2 | E68, E78 | 3 | 1.17 |
| 48 | 2 | E69, E78 | 5 | 1.95 |
| 49 | 2 | E70, E78 | 1 | 0.39 |
| 50 | 2 | E71, E78 | 3 | 1.17 |
| 51 | 2 | E72, E78 | 1 | 0.39 |
| 52 | 2 | E73, E78 | 5 | 1.95 |
| 53 | 2 | E75, E78 | 2 | 0.78 |
| 54 | 2 | E76, E78 | 8 | 3.13 |
| 55 | 2 | E77, E78 | 3 | 1.17 |
| | | | 256 | |

Table 4.5 Class members' participation on blog

Table 4.5 shows the sizes of cliques that formed, those participants, as denoted with E, that are involved, their number of messages and percentage of participation during the activity. This shows how much each small group that communicated, contributed to the overall discussion. During the blog activities, the instructor's influence is higher than that of the students because he posted more messages than any student did, thereby making many ties towards the teacher as shown in Figure 4.7. The two diagrams in Figure 4.7 are the same except that one is labelled E78 to indicate the instructor's position in the network. The instructor initiates the interaction by posting a topic of discussion on the blog, and without his role the network structure would be different.

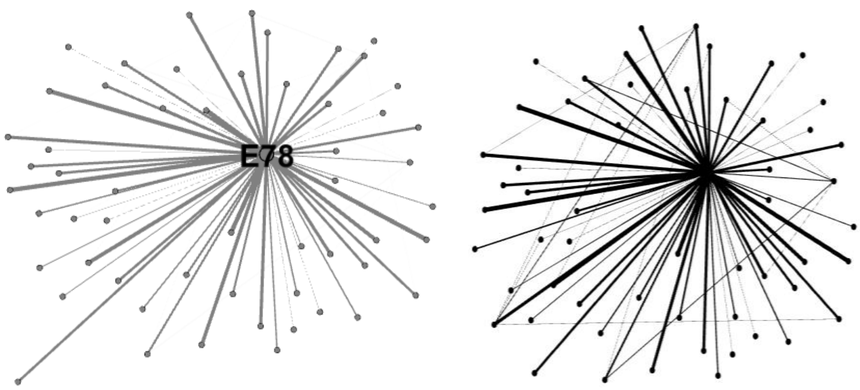



Figure 4.7 Social network structures of participants on the blog (the instructor is labelled E78, other nodes surrounding are the students).

There are students (i.e. nodes) that did not post or reply to any message; rather they may have come to the blog and read other's messages and left the online community. Those students are represented in Figure 4.8 with 21 yellow squares that had no tie or link to anyone. All the unconnected nodes are also class members but did not participate; these are lurkers (i.e. they come and read on the blog and made no comment). Only those students who participated are shown in Figure 4.7. Since Figure 4.7 did not show the students who did not participate at all during the blog activity, to show the non-participating class members, an extended diagram is required. Therefore, Figure 4.8 was produced to show both those who participated and those who did not.

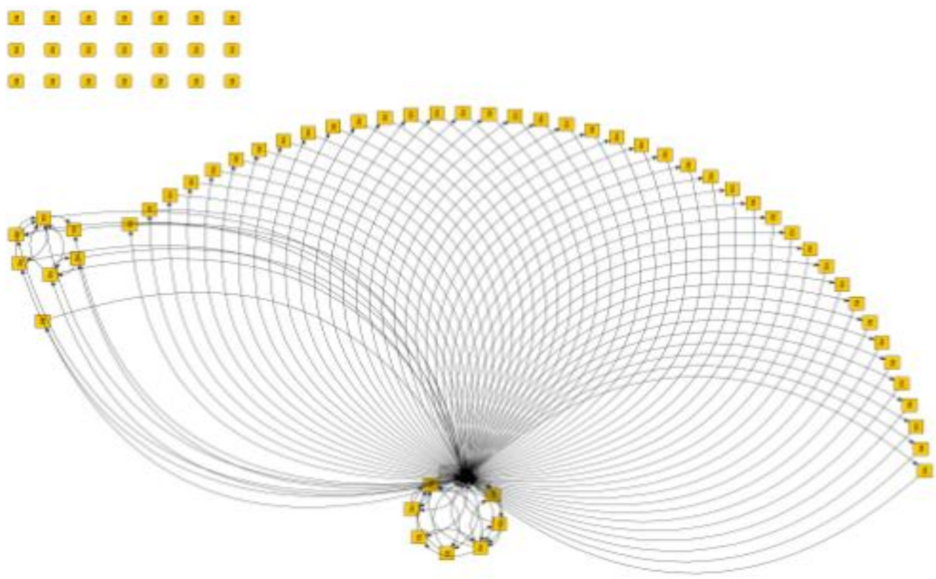


Figure 4.8 Social network structures of blog activities.

Figure 4.8 shows the 21 non-participants on the blog. The instructor is represented by the black spot at the centre, and other yellow squares are the nodes surrounding, i.e. the students. The two small networks called sub-networks are shown in Figure 4.8.

**4.2.4.2 Building a dataset – the Facebook profile and data**

Data were retrieved from the group page and the statistic is shown in Table 4.6 and the plots are equally shown, see Figure 4.9 and 4.10, on pages 210 and 211. Table 4.6 shows the magnitude of students' posts (P), comments (C), and reactions (R) which were returned as feedback to every participant in the class and outsiders as they learn.

| Period | Reactions ( R), Comments (C), and Posts (P) | | | | | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| $25^{th}$ - $30^{th}$ Aug. | | 11R,<br>9R,<br>13R, 1C,<br>9R, | 11R,<br>10R,<br>11R,<br>18R, 3C | 24R,9C,<br>19R,4C,<br>1P | 11R,3C,8R,2C,<br>1P,1R,<br>1R, 1C,1P,<br>1R,1P, 2R, | 18R,10C,<br>1P,1R,<br>15R, 1C,<br>1P,14R,<br>1C | 11R,2C,<br>13R,1C, | **231R,36C, 6P** |
| $31^{st}$ – $5^{th}$ Sep. | 4R, | 4R,1C, | | | 10R,4C, | | | **18R,4C,** |
| $6^{th}$- $10^{th}$ Sep | 1P,6R, | 1P,1R, | 12R,8C, | 1P,9R,1C, | | | | **28R,3P,9C** |
| $11^{th}$ - $16^{th}$ Sep. | 15R,7C, | 10R,18C, | 1R | 6R,1C, | | | | **32R,26C** |
| $17^{th}$ - $21^{st}$ Sep. | 1P,3R, | 1P,2R,1C | 1P,2R,1C | 2R,1C | 8R | 8R,4C, | 1P,2R,1C, | **27R,4P,8C** |

| Period | Reactions ( R), Comments (C), and Posts (P) | | | | | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| $22^{nd}$ – $27^{th}$ Sep | | 9R,4C, | 3R,4R, 6R,2C, | 11R,6C, | | | | **33R,18C,** |
| $28^{th}$ – $3^{rd}$ Oct | | | 3R | 15R,6C, | | | | **18R,6C** |

Table 4.6 The student-teacher interactivity in the six-week period on the class's Facebook page.

Data were retrieved from the group page and the values are shown in Table 4.7. The SNS features a general graph arising from comments, reactions, and posts. The metrics are detailed in Table 4.7. These values were automatically produced by the software after I put the dataset values into the *Gephi* software.

| **s/n** | **Metrics/network descriptive** | **All interactions** | **Reactions** | **Comments** | **Students' Posts** |
|---|---|---|---|---|---|
| 1 | Nodes: | 57 | 56 | 39 | 40 |
| 2 | Ties : | 202 | 187 | 89 | 98 |
| 3 | Diameter: | 3 | 3 | 4 | 5 |
| 4 | Radius: | 2 | 2 | 2 | 3 |
| 5 | Average Path length: | 2.070 | 2.077 | 2.032 | 2.542 |

| s/n | Metrics/network descriptive | All interactions | Reactions | Comments | Students' Posts |
|---|---|---|---|---|---|
| 6 | Average Degree: | 0.088 | 3.357 | 2.308 | 2.450 |
| 7 | Average weighted degree: | 30.211 | 27.143 | 11.077 | 6.500 |
| 8 | Network density: | 0.063 | 0.061 | 0.061 | 0.063 |
| 9 | Eigenvector centrality:<br><br>Number of iterations:<br><br>Sum change: | Undirected<br><br>100<br><br>5.834 | Undirected<br><br>100<br><br>6.347 | Undirected<br><br>100<br><br>2.298 | Undirected<br><br>100<br><br>6.224 |
| 10 | Average Clustering Coefficient: | 0.774 | 0.783 | 0.789 | 0.315 |
| 11 | Total triangles: | 50 | 43 | 8 | 6 |

Table 4.7 Metrics of Facebook's Interactivity

Reactions, Comments, and Posts are all Interactions. There are four columns that represent network structures in Table 4.7. The clustering coefficients are 0.774 when all the three are considered, i.e. 0.783 for Reactions, 0.789 for Comments, and 0.315 for the posts made by students alone. Since a neighbourhood that is fully connected has a coefficient of 1 and that with less connection has a zero, that implies that there are more interactions in the reactions and comments during the Facebook activity. The posts from students did not make impressive connection as 0.315 is much less than 1. The network is an undirected type as messages that leaves a source can reach any node in the network. Other metrics that explain the interactions include the network densities of 0.063 and 0.061; the nearer the value is to 1, the denser is the network and the more cohesive are the nodes in the network. The average weighted degrees of 30.211 (i.e., high value) and 6.500 (i.e., low value) indicate how many times those edges are traversed between a pair of nodes. It implies that in the network structure formed by all reactions, comments, and students' posts, the ties between the nodes have been traversed many times more than the weighted degrees of only comments or reactions whose values are 27.143 and 11.077. This means that more participants have read or used the online information of the network structure of 30.211 to a weighted degree than that of 27.143 and 11.077. The average degree is the tendency of having sufficient ties (i.e., messages) across the network to connect all the nodes (i.e., participants); the values of 3.357 and 0.088 are highest and lowest as shown in Table 4.7. The average path length is the measure of efficiency of information flow within the social network, meaning that information flow is more efficient when all the reactions, comments, and students' posts are collectively considered than in any single or individual network structure of reactions, comments, or students' posts. The number of ties and nodes, and the diameter vary among the structures to show that 57 participants are intertwined by 202 messages while 39 participants are connected by 89 messages only in the network structure that Comments could form.

Recalling from section 3.9.5 that these values above are showing the pattern of conversation that happened among the participants in the Facebook group, the interpretation is that there are three structures (and their information) that emerged during the communication amongst students and teacher in the Facebook group. For instance, 43 possible triangles (i.e., three participants that are linkable by ties) in the network structure of the reactions that each participant responded to in a post, comment or post, and this tells us that when the entire network structure is put into all possible triads, i.e., three participants, that the maximum is 43. The diameters indicate how separated the farthest nodes are that can be traced when a circle is drawn or formed over the network structure. The higher values such as 5 indicate more separateness than a smaller value of 3. The diameter is the lengthiest graph distance between two nodes in the network, which is how far apart the two farthest nodes are.

#### 4.2.4.2.1 Analysis of collaboration by SNA plot of Facebook and its message analysis

After plotting the network graphs, from the plot, the collaborating groups identified by the SNA tool are shown in Table 4.8.

| Discussant groups | Size of participants (including the teacher) | Members of the group | On-task message + Off-task message that could be an icebreaker | % contribution to participation |
|---|---|---|---|---|
| 1 | 23 | E82, E4, E74, E83, E28, E22, E64, E84, E80, E67, E73, E52, E8, E53, E51, E21, E66, E81, E46, E58, E78, E34 | 23 | 4.67 |
| 2 | 23 | E46, E34, E8, E89, E32, E71, E86, E61, E85, E80, E44, E76, | | 9.33 |

| | | | | |
|---|---|---|---|---|
| | | E4, E22, E33, E79, E74, E28, E87, E40, E39, E17, E78. | 46 | |
| Discussant groups | Size of participants (including the teacher) | Members of the group | On-task message + Off-task message that could be an icebreaker | % contribution to participation |
| 3 | 6 | E4, E33, E41, E46, E34, E78. | 19 | 3.85 |
| 4 | 5 | E74, E34, E46, E15, E78. | 20 | 4.06 |
| | 5 | E90, E15, E35, E80, E52. | 4 | 0.81 |
| | 5 | E41, E4, E33, E15, E78. | 14 | 2.84 |
| | 5 | E80, E34, E46, E90, E78. | 15 | 3.04 |
| | 5 | E33, E4, E41, E46, E78. | 23 | 4.67 |
| | 5 | E15, E74, E41, E90, E78. | 13 | 2.64 |
| 5 | 4 | E39, E64, E46, E78 | 20 | 4.06 |
| | 4 | E64, E39, E34, E78 | 13 | 2.64 |
| | 4 | E52, E34, E90, E78 | 15 | 3.04 |
| | 4 | E22, E34, E46, E78. | 21 | 4.26 |
| | 4 | E8, E34, E46, E78. | 16 | 3.25 |
| | 4 | E28, E46, E34, E78 | 14 | 2.84 |
| 6 | 3 | E71, E46, E78. | 8 | 1.62 |
| | 3 | E51, E34, E78 | 9 | 1.83 |
| | 3 | E85, E46, E78 | 3 | 0.61 |
| | 3 | E82, E34, E78. | 2 | 0.41 |
| | 3 | E53, E34, E78 | 3 | 0.61 |
| | 3 | E44, E46, E78 | 2 | 0.41 |
| | 3 | E76, E46, E78. | 9 | 1.83 |
| | 3 | E35, E90, E78. | 22 | 4.46 |
| | 3 | E77, E62, E78 | 6 | 1.22 |
| | 3 | E86, E46, E78 | 6 | 1.22 |
| | 3 | E89, E46, E78 | 3 | 0.61 |
| | 3 | E40, E46, E78 | 4 | 0.81 |

| Discussant groups | Size of participants (including the teacher) | Members of the group | On-task message + Off-task message that could be an icebreaker | % contribution to participation |
|---|---|---|---|---|
| | 3 | E79, E46, E78 | 6 | 1.22 |
| | 3 | E81, E34, E78 | 2 | 0.41 |
| | 3 | E66, E34, E78 | 4 | 0.81 |
| | 3 | E17, E46, E78 | 12 | 2.43 |
| | 3 | E58, E34, E78 | 10 | 2.03 |
| | 3 | E62, E78, E77 | 12 | 2.43 |
| | 3 | E32, E46, E78 | 3 | 0.61 |
| | 3 | E61, E46, E78 | 18 | 3.65 |
| | 3 | E73, E34, E78 | 5 | 1.01 |
| 7 | 2 | E84, E34 | 1 | 0.20 |
| | 2 | E21, E34 | 1 | 0.20 |
| | 2 | E14, E78 | 3 | 0.61 |
| | 2 | E67, E34 | 1 | 0.20 |
| | 2 | E56, E78 | 5 | 1.01 |
| | 2 | E42, E78 | 6 | 1.22 |
| | 2 | E36, E78 | 3 | 0.61 |
| | 2 | E65, E78 | 3 | 0.61 |
| | 2 | E46, E87 | 1 | 0.20 |
| | 2 | E7, E78 | 2 | 0.41 |
| | 2 | E19, E78 | 8 | 1.62 |
| | 2 | E27, E78 | 1 | 0.20 |
| | 2 | E68. E78 | 2 | 0.41 |
| | 2 | E57, E78 | 1 | 0.20 |
| | 2 | E50, E78 | 6 | 1.22 |
| | 2 | E88, E78 | 3 | 0.61 |
| | 2 | E24, E78 | 3 | 0.61 |
| | 2 | E69, E78 | 17 | 3.45 |

| Discussant groups | Size of participants (including the teacher) | Members of the group | On-task message + Off-task message that could be an icebreaker | % contribution to participation |
|---|---|---|---|---|
| | 2 | E70, E78 | 1 | 0.20 |
| | | | 493 | |

Table 4.8 Class members' participation on Facebook

Table 4.8 shows the sizes of cliques that formed, those participants, as denoted with E, that are involved in each group, their number of messages and percentage of participation during the activity. This shows how much each small group that communicated contributed to the overall discussion.

Figure 4.9 shows a simple display of how the students are connected by messages on Facebook viewed by *Gephi*. The largest grey node, by the right-hand side, connecting all other nodes is the teacher, and the two largest black nodes with numerous ties are two students E34 and E46. The red nodes and ties are the non-class members who participated. The thickness of each tie implies how heavy or thin are the messages exchanged between two nodes. From the plot, the collaborating groups identified by the SNA tool are shown in Table 4.8. There are two groups that have the largest number of participants; they have 23 participants and those two are led by two students who have the nodes with most ties (i.e., lines or connections) as visibly shown in Figure 4.9. In Figure 4.9, there are three large nodes with the largest number of connections or lines, two are black and one is grey, and this is the instructor. The two students led the two largest sub-networks with 23 nodes (i.e., participants) in each sub-network. A sub-network is a small network inside the entire network. Since Facebook is an open space for everyone, the red nodes and ties are the non-class members who participated, and the red lines (ties) are their messages.

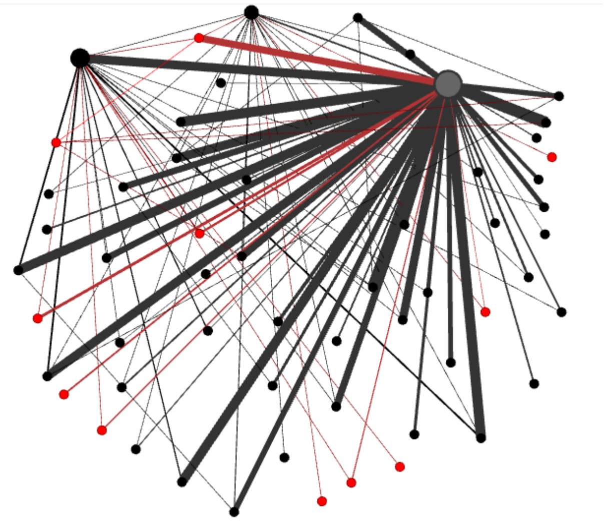


Figure 4.9 Social network structure of participants` interactions on the Facebook

In Figure 4.9, the big grey circle represents the instructor, the red circles represent the non-class members while every other circle is a class member, i.e., the students. And the lines joining them are the ties, i.e. their messages.

One limitation of Figure 4.9 is that it does not show the students who did not participate at all during the activity. To show the non-participating class members, Figure 4.10 was produced, using the same information, to show both those who participated and those who did not. The participation of non-class members introduced more ties in the network structure. However, there are class members who neither posted nor reacted to any of the instructor's and students' posts and those are indicated with unconnected yellow squares shown in Figure 4.10. In Figure 4.10, the non-class members are indicated with purple circles and all non-class members that appeared also exchanged messages within the entire network and sub-network.

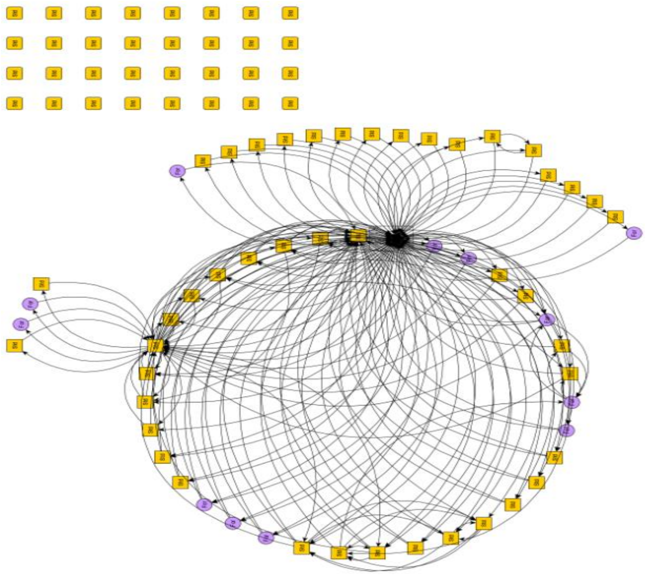


Figure 4.10 Social network structure of Facebook activities

Figure 4.10 shows the non-participating class members represented by the unconnected yellow squares, the participants who interacted on Facebook are represented by the connected yellows and purples. The black spot represents the instructor and the purple circles present the non-class members while every yellow shape is a class member.

#### 4.2.4.3 Indicators: Centrality measures of blog and Facebook class activity

According to Borgatti et al. (2013), centrality depicts more about the mainstay of a social network because it specifically deals with the nodes, i.e., participants, and ties, i.e. their messages. During the data retrieval from the blog and Facebook group page as shown in Tables 4.4 and 4.7, the centrality values were also computed automatically and the centrality values were exported to spreadsheets to compute their relationship and interpret their meaning using the descriptive statistics as shown in Tables 4.9, 4.10, and 4.11. There are three forms of centrality that are important to explore, and these are closeness, betweenness, and degree centrality. The same explanation applies to Tables 4.9, 4.10 and 4.11, and the five columns that have values. The blog has only one column, the Facebook has four columns; that is one for students' posts, one for reactions, one for comments to posts, and one column with the sub-heading 'ALL' is for all the students' posts, reactions, and comments in the Facebook group. The Tables 4.9, 4.10, and 4.11 indicate statistically how values inform about the interaction and exchange of information in the SNS. For instance, in closeness centrality, the mean values are 0.375 for blog, and 0.445 for Facebook group, shows how close a node is to all other nodes in the network, and it has a mean of 0.375 and 0.445 for blog and Facebook respectively. This implies that collaboration prospered more effectively in Facebook than the blog as 0.445 is bigger than 0.375.

The standard deviation is how data spread out from the mean. In Table 4.10, in betweenness centrality, the values of 0.057 for the blog and 0.029 for Facebook indicate that the low 0.029 standard deviation shows that the data points tend to be close to the mean of 0.005, while a high standard deviation indicates that the data points are spread out over a wider range of values. A high betweenness shows that someone is highly influential during interaction across all the sub-networks. The 0.007 and 0.005 of blog and Facebook respectively reflect that a node is highly influential on the blog on average and that is the instructor and that is fairer than 0.005 that tells how influential a node is on average.

Closeness centrality

| *Closeness Centrality* | *Blog* | *Facebook Metrics* | | | |
|---|---|---|---|---|---|
| | | *Posts* | *Reactions* | *Comments* | *ALL* |
| Mean | 0.375 | 0.500 | 0.508 | 0.508 | 0.445 |
| Standard Error | 0.027 | 0.005 | 0.006 | 0.006 | 0.004 |
| Median | 0.505 | 0.492 | 0.503 | 0.503 | 0.462 |
| Mode | 0.505 | 0.492 | 0.503 | 0.503 | 0.458 |
| Standard Deviation | 0.238 | 0.047 | 0.053 | 0.053 | 0.042 |
| Count(n) | 77.000 | 90.000 | 89.000 | 89.000 | 110.000 |
| Confidence Level (95,0%) | 0.054 | 0.010 | 0.011 | 0.011 | 0.008 |

Table 4.9 Closeness Centrality Measures of Blog and Facebook Class activity.

Betweenness centrality

| *Betweenness centrality* | *Blog* | Facebook | | | |
|---|---|---|---|---|---|
| | | Posts | Reactions | Comments | ALL |
| Mean | 0.007 | 0.001 | 43.011 | 0.011 | 0.005 |
| Standard Error | 0.007 | 0.000 | 43.011 | 0.011 | 0.003 |
| Median | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Mode | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Standard Deviation | 0.057 | 0.004 | 405.767 | 0.106 | 0.029 |
| Count(n) | 77.000 | 90.000 | 89.000 | 89.000 | 110.000 |
| Confidence Level(95.0%) | 0.013 | 0.001 | 85.476 | 0.022 | 0.005 |

Table 4.10 Betweenness Centrality Measures of Blog and Facebook Class activity

Degree centrality

| *Degree centrality* | *Blog* | Facebook | | | |
|---|---|---|---|---|---|
| | | Posts | Reactions | Comments | ALL |
| Mean | 1.714 | 0.104 | 0.106 | 0.105 | 0.040 |
| Standard Error | 0.710 | 0.001 | 0.000 | 0.000 | 0.008 |
| Median | 1.000 | 0.107 | 0.106 | 0.105 | 0.010 |
| Mode | 1.000 | 0.107 | 0.106 | 0.105 | 0.004 |
| Standard Deviation | 6.232 | 0.012 | 0.000 | 0.000 | 0.087 |
| Count(n) | 77.000 | 90.000 | 89.000 | 89.000 | 110.000 |
| Confidence Level(95.0%) | 1.415 | 0.002 | 0.000 | 0.000 | 0.016 |

Table 4.11 Degree Centrality Measures of Blog and Facebook Class activity.

**4.2.4.3.1 Sub-group or sub-network**

In this study, I used sub-groups, sub-networks, and cliques to describe how the students automatically were grouped, not by their instructor but unintentionally and sporadically by their learning behaviours. The clustering of nodes, i.e., discussants to form a sub-network or sub-group, indicates that collaboration in a social connection may not be pre-arranged or organised because online participants can navigate easily. Collaborating groups of students share a common interest or other factors could be responsible for why they come together. On the blog, there are forty-two dyads. The minimum size of a clique is a dyad, i.e. a two-member sub-network (Hanneman &

Riddle, 2005). There are also nine 3-member, two 6-member, one 4-member, and one 5-member sub-groups.

And there are various sizes of sub-groups on the Facebook site, the dyads, triads, etc., and those above twenty-member sub-networks. Two students E34, and E46 lead a large member sub-network of over twenty nodes, i.e. members or discussants. E34 and E46 held twenty-member and twenty-one cliques respectively. And two 3-member sub-networks were held by two non-class members that appeared on the network, E80 and E90. There are nine triads, and these triads are led by influential nodes, i.e. anchoring node, E4, E15, E28, E33, E39, E41, E74, E80 and E90. On Facebook, there is one 6-member, eight 5-member, six 4-member, twenty-one 3-member, and twenty-one 2-member cliques. It is evident there are more sub-groups on Facebook than on the blog.

#### 4.2.4.4 Findings of social network and message analysis

After investigating the blog and Facebook activities during the time of class activities according to heterogenous partitioning by SNA, the same lesson's topic was put on both SNS for the students. These prominent results explain the extent of students' engagement. There are a total of 256 and 493 messages on the blog and Facebook respectively. This constitutes reactions, comments, and posts. The results from Tables 4.5 and 4.8 indicated the sizes of on-task messages and off-task messages. Off-line messages may not be context or engineering related but it could be an icebreaker for the entire discussion. A tie is a connection between two or more individuals (i.e. nodes) by a message. A message is counted in the form of a two-way passage of information between two individuals. In Table 4.5 (i.e. blog), the 6-member group had a highest value of 11 messages, a 3-member group had 10 and a 2-member group 8. On the same space, another 6-member group made 6 messages, another 3-member group made 2 and a 2-member group made just a single message. Also, in Table 4.8 (i.e. Facebook), a 23-member group made 46 messages, a 3-member group made 22, and a 2-member made 17 messages. On the same space, another 23-member group made 23 messages, a 3-member group made 2 messages, and a 2-member group made a single message. The wavering numbers indicate that there are more reasons why the students clustered more than other groups during learning if they are not divided into equal collaborating groups. It is obvious from the figures that there is proportionally more interactivity in Facebook than the blog.

As shown in the Tables 4.5 and 4.8, percentage participation of every group formed indicates that when students are voluntarily collaborating in learning, there is no verdict that a larger size of participants were more engaged than a fewer size or vice-versa. This affirms that students' engagement may be liable to other inherent phenomena other than size of collaborators. Tables 4.4 and 4.7 show that the densities of blog and Facebook were 0.043 and 0.063 respectively. The difference in densities showed that more participation occurred on Facebook than on the blog. Tables 4.5 and 4.8 show that there are 256 to 493 messages for the blog and Facebook page respectively. The finding showed that to motivate students, the density of the interactive surface should increase toward unity. A value less than 1 indicates little interaction. A low-value density group delivers small centrality, less interactions, and low collaboration. Small cohesive groups give high density and do better in online collaborative learning (Akcaoglu & Lee, 2016, p.2; Saqr, Fors & Nouri, 2018, p.17). As shown in the network structures in Figures 4.7 and 4.8, the presence of non-class members on the social network enhanced the emergence of more ties in the network structure and this implicitly means that popular SNS creates more links and attraction. Notwithstanding, even though Facebook indicated a higher network density, implying stronger cohesion than the blog, many participants did not post or comment.

Therefore, the non-class members of the groups (the coloured red ties and nodes) are students who are not members of the class but have the same professional goal, who migrated from other study groups to invigorate the Facebook group under study. It implies that the SNS motivation can be increased by introduction of larger interactive surfaces of like-minded learners outside the boundary of teaching. It reinforces the benefits of creating a free social learning space whereby learners interact with non-class member learners to boost their interest and knowledge. However, Gunawardena et al. (2016, p.22) perceived that learning is not completely a cognitive process but is situated within a social context.

Tables 4.9, 4.10, and 4.11 disclose the three centralities of both SNS; they are not for comparison but for explanation of what transpired during the class activity. For the closeness centrality, these are 0.345 and 0.445 for the blog and Facebook respectively. Even though these values are incomparable because of varied numbers of nodes, however it reinforces the fact that participation varied as well as number of participants on both SNS. These values indicate that on average, the length of the shortest path between a node and all other nodes may seem better on the blog than the Facebook. However, closeness centrality needs a fully connected graph to be perfect (Okamoto et al., 2008; Opsahl et al., 2010), and the blog is not fully connected as shown in Figures 4.7 and 4.8. Many students did not communicate to one another except to the teacher.

The values are 0.007 and 0.005 for betweenness centralities for the blog and Facebook respectively; this is an indication of the controlling influence of information and knowledge distribution among the discussants. Also, the degree centralities manifest as 1.714 and 0.040 for blog and Facebook sites respectively, indicating simple measures of how many neighbours a node (i.e. participant) has. The teacher has the highest influence on the blog more than on the Facebook. A node's highest influence is on the blog and lowest on the Facebook. However, this implies that one node is more connected to more neighbours on the blog than one node's highest connections on Facebook. It is an indication of weak participation (i.e., exchange of messages) amongst the entire network structure. In SNS, learning takes the form of participation and identity formation through everyone's engagement in and contribution to networked practices (Veletsianos, 2012).

#### 4.2.4.4.1 Reasons behind high and low students' participation on the SNS that affected data sharing and conversation

Out of the entire 76 class members, there were 32 and 21 lurkers (students who did not participate on the Facebook class discussion and blog respectively, i.e. those unconnected nodes). There were 12 non-class member students that joined them on the Facebook, and they helped push interaction and collaboration. Despite there are more ‘lurkers’ on Facebook than the blog, collaboration and interaction are higher on Facebook than the blog. The students said they do not know the non-class members. There were no non-class member students on the blog because it had restricted access. The non-class members’ data were not analysed since consent and permission from them was not possible to obtain. The students who did participate highly on the blog and low on Facebook state that Facebook has more distractions than the blog, and they gave more time to blog activities. And other students with high participation on Facebook and low on the blog stated that they visit Facebook more regularly than the blog because of entertainment and that the blog does not have social attractions. Respondent #8 said:

> Almost of the time there’s no entertainment and affairs in the blog unlike Facebook, so that is why I don’t visit the blog all the time.

Mixed feelings surround the reason some Facebook users are addicted to it while some shy away from it (Bodroža & Jovanović, 2016, p.425;  Maiz et al., 2016, p.632). However, more students indicated their inclination to social media especially Facebook. Social media was found to promote positive peer interaction (Firipis et al., 2018, p.53).

According to analysis, the students further expressed and shared their recommendations. Students with low participation on both sites do not have interest in online activities and internet cost, and students with high participation on both stated it was out of passion for learning. Respondent #12, with the highest leading of cliques (i.e. a sub-unit of the entire network), said:

> Many students found I had interest in it, so everybody was trying to know why I had interest in the blog and the Facebook. So many people were coming there to see if they can learn from me and ask question.

They expressed the hindrance to data sharing on the SNS included the absence of facility voice note or recording, used for answering class questions rather than typing every time as typing takes more time than audio data. A teacher asking questions to students by audio rather than texts could be used they suggested, and that can even be a better feedback mechanism for the teacher and students since the audio channel is hands-free and students' hands are busy on the practice tools. Typing texts on the mobile keypads is stressful and takes their study time. Also, students could not meet often, and online presence was not organised, and some could not follow properly as there is no schedule of when they should come online; asynchronous meetings deterred their learning participation, as respondent #6 said:

> Collaboration, sometimes most all of us are active during the learning on the blog. So, sometimes some people are left behind and lots of them do not flow through with it.

The students suggest that due to high internet cost, the synchronous mobile learning that will fit their environment is everyone appears online at a scheduled time and date, then do some class activity and dismiss or disconnect.

According to the students, they outlined that there is an error of the SNS as a learning space, that the lurkers may even create learning more than the online participated students because there is online stealing of information by disguised participating students. Respondent #18 said:

> On the blog, the students are copying each other, it doesn't help anybody grow. So, I think submitting our personality to the teacher via a space or voice on the sites should be made available

In summary, the collaboration on the mobile social network for the purpose of learning and gaining expertise showed that connection and interaction exist prior to data sharing, and conversation, participation and message exchanges are evidences of collaboration. The students' participation was factored to be related to basically contents, interface and platform related. An attractive platform did not allure students' interest, and distraction dissuaded some students too. In May and Ossenberg (2016; 2015), a study of meaningful interaction and collaboration with the help of mobile devices in the learning of an engineering course, it suggests that mobile devices support collaboration among students. Also, by using social media in mobile engineering learning, it produces additional engagement, interaction and collaboration (Khan & Chiang, 2014).

## 4.3 Summary

This chapter explored the research questions and found answers. It has covered when and where the students could use mobile technologies to learn and practice. Also, it detailed the students' perceptions of authenticty of engineering practices performed using the mobile tools, how they created their own learning by customising activities, and how collaboration was achieved on social media for learning purpose. The next chapter will discuss in detail the findings of this chapter and connect them to an understanding of mobile engineering learning and how it can be achieved using the answers to the research questions.

# Chapter 5 - Discussion, Conclusions, and Further Work

## 5.1 Overview

This chapter discusses the following: Answering the research questions, Contributions of research to theory - filling the research gap, Contributions of research to the theoretical framework, Implications of findings to teaching practice, Recommendations for policy in the use of mobile technologies in engineering education in academic institutions, Recommendations for engineering teaching practice, Summary of findings, Limitation and weaknesses of the research design, and Suggestions for further research.

## 5.2 Summary

Spatiality and temporality, i.e., space and time, of mobile learning in engineering relies fundamentally on a student's ability to position their priorities over limitations associated with the mobile learning space (where and when), and technology (device, tools, platforms, techniques, content, standards, etc.). This study theorises that students learn with what tools are available in their social space and adapts to every other issue disfavouring mobile learning.

That the students' practices over the mobile environments are real is evinced by the relevance of their engineering education, in both theory and practice as found in this study. And it relies on the students', tasks', tools', and setting's attributes. The level of exposure of a student aids in realising performances that are in line with the context and professional practice. Some tasks are perceived as tough, arising from usability issues. When they are demotivated by technical limitations such as content issues, they fail to attain authentic performances. However, students developed adaptabilities, approaches, and tactics inherently from their experience of using a device, with which they evade the drawbacks of mobile tools.

The steps to attaining personalisation encompasses students' familiarity with each task and process, knowing the choice of tools that suits the tasks. If the students are not very familiar with all of them, getting assistance from external sources (scaffolding) is the only way to reduce the long time required during transitioning from novice to expert. Recalling that on page 173, under the sub-section 'Assistance from others', respondent #7 asserted that the social media and YouTube are the major places that give them deeper understanding of what to do while they practice.

Most assistance they receive during practice and learning emanates from social media. Scaffolding begins to unwrap from their first year in university and rise to their industrial training programme. Their engineering tasks can be individually and collectively based depending on the platform.

Students from debilitated educational settings admit that mobile devices are very affordable, limitations are matched with adaptability, and they stick to using it to learn; however, improper appropriation of mobile learning in FUOYE university has not helped engineering learning as revealed in sub-section 4.2.2.1.3.2 under the heading 'institutional support and interference'. So, there are some engineering courses and laboratory practices that mobile learning support, and practices that students can do on suitable platforms which have been found in this study. The teaching staff will be guided by these findings to appropriate content in the mobile platforms since mobile tools are the cultural resources of the engineering students of FUOYE (Pachler et al., 2013, p.182). Mobile learning cannot substitute for a completely physical laboratory but to some extent it can be supportive in practices of electrical and electronic engineering in FUOYE. It plays a big role in advancing expertise and knowledge acquisition in students, for instance, Figure 4.6 shows how the mobile App could connect a small size surveillance robotic rover via Wi-Fi and control a rover while streaming the camera in the rover.

In practising engineering tasks, students create their learning mainly in an offline and online mobile environment, across all platforms in varying degrees, in and out of school as shown in Table 4.1, and sections 4.2.1.1.2.1.1 and 4.2.1.1.2.1.2 explaining Table 4.1 in the previous chapter.

In summary, in the use of mobile engineering learning, the study revealed how students facilitate learning using mobile technologies, especially for improving their engineering skills. They accomplish their learning objectives by customising tasks and creating real-world engineering meaning from their individual and group work. When they practice in groups, mostly they do theoretical learning, but hands-on practice is mainly done individually. That was shown in sub-section 4.2.3.4.2 where the study found the individual and group experience of mobile learning. The experience is that working in groups saves time despite the fact that a group activity's result is not the same as an individual's result.

They appear on mobile social environments to seek ideas from online users, with which they return to their individual activity to advance their learning progress.

The gap identified in the literature is the users' perspective that is required to provide insight in the field of engineering, and it was accomplished by the findings of this study. The user experience is vital in designing and integrating mobile technologies for learning purpose (Aranburu et al., 2019). The results will help engineering instructors anywhere who share a similar context, as it shows what students can and cannot do in engineering education with mobile tools. As detailed in sub-section 4.2.2, the study unpacked the portions of technologies, tools, nature of tasks, and implementation approaches that favour or do not favour mobile engineering learning. The following are possible in mobile engineering learning: wiring, programming, measuring, calibrating, simulating, testing, designing, lecture taking, completing assignments, drawing, analysing circuit, workshop practicing, trouble shooting, data transferring, documenting, and messaging. It also provided recommendations and prospects that support students' expertise, whether on an individual or networked basis because mobile learning provides an interactive and adaptive learning environment.

### 5.3 Answers to Research Questions

The findings broadly cover the research questions and the way the investigation outcome comes from a socio-cultural perspective. Jin et al. (2019), suggest that students' socio-cultural background, and their previous experiences, need to be carefully considered to successfully adopt mobile devices in the local context. For that, I carefully answered the research questions from the information gathered in this study. A mobile learning pedagogical model was used to view and organise this study into a structure of four research questions.

### 5.3.1 Spatial learning diverse - location and when the students do mobile learning

The results from sub-section 4.2.1 showed that students use mobile learning through two broad kinds of perspectives of where mobile learning takes place: one is the physical space called in-school and out-of-school, and another is the digital space called mobile platforms, i.e. online and offline sites that encompass LMS, toolbox, social media and mobile Apps.

In-school and out-of-school are for different learning activities or engineering tasks based on the relevance to those two respective places. In-school use is intended to support class lessons, collaboration with peers, do practices that are the lessons of the day. And out-of-school, the use of mobile learning is predominantly leading in personal learning and research. Learning tasks that are difficult appear to be more handled in-school such tasks that are reliably done in the complex mobile Apps such as AutoCAD, Python, and MATLAB. Those tasks on complete mobile Apps often required assistance and rarely matched a student’s competence and self-efficacy. Low self-efficacy makes them do soft tasks when they are out of school, such as reading circuit diagrams. Ma et al. (2016) hints that when engineering students use mobile tools, self-efficacy is intertwined in the tools.

Mobile learning appears in two forms, namely online and offline. However, they use offline more than online for one reason. Accessing online sites requires internet subscription and coming from low-income families the students cannot afford the high cost of internet subscriptions. Therefore, major Apps are downloaded through online and then used as a stand-alone App.

Mobile learning activities analysed by temporality and spatiality i.e., time and space, provides a nuanced interpretation that describes and articulates the underpinnings of quality mobile learning and pedagogy (Schuck, 2015, p.2). Since distinctive experiences occur in space and time, spatially-embedded learning activities become necessary for evaluation (Bligh & Crook, 2017). Issues and concerns relating to negative perceptions of m-learning are embedded spatially because where and when activities happen decides what skills are acquired and how (Nikou & Economides, 2018). This formed a foundation for other research questions. All tasks are suitable for in-school or out-of-school, it is totally subject to user’s choice of time and where. Subjective norms have the strongest impact over other behavioural controls (Yeap et al., 2016, p.14).

Furthermore, students’ perceptions of what can be achieved through mobile technologies led them to decide when they used mobile learning (Hashim et al., 2009). In choosing spots for location of use, they consider whether it is for sole or group use, and this is equally subjective. Some kinds of tools are outstanding for learning, e.g. YouTube. Devices lower than version 8.0 Android were not able to do most tasks. And ignorance of a tool’s potentials can hinder students in choosing the right tools.

Mobile learning fitted well in helping their studies during social issues, e.g. lockdown due to pandemic, shut down of university due to strike, etc.; for instance, university education is prone to incessant strikes in Nigeria (Monogbe, 2019, p.60). So, the students adopt mobile learning as the only panacea to the educational crisis as this study found.

Task concepts and nature of them are another pointer to where they adopt mobile learning and this is also mentioned by Mileva (2011). The students’ choices depend on what they need to perform in technical and non-technical tasks, and these depend on cost, experience, priority, and nature of the learning activity.

In summary, the spatial perspective revealed that dual conceptions can be used to describe their locations of mobile learning adoption. And those physical and digital locations are totally conditioned by surrounding factors that the students cannot control. The choice of adoption of mobile tools is dependent upon where a student deems it fit to use (Yeap et al., 2016). Moreover, Schuck et al. (2010, p.70) also highlighted the role location plays in selecting mobile tools for learning purposes.

### 5.3.2 Perception of the authenticity of practices performed through mobile technologies

Exploring the contextualisation and situatedness of engineering mobile learning revealed insights with respect to students' learning, class tasks and practices in the context of their courses. Contextualisation related the reality of students' practices to the learning context, and situatedness of those students' practices is the reality of their learning activities related to authentic engineering practice (Schuck, 2015, p.2). According to information in sub-section 4.2.2, the study found that there is accord of students' practices and their courses' contents with respect to the sequence of tasks and procedures to follow when doing tasks using the laboratory manuals and accomplishing those procedures with mobile tools to deliver expected results. And there is connectedness of the outcomes of their tasks, such as assignments and projects, to real-world engineering. However, standardisation issues posed a significant challenge to the students from this region of the world because major online platforms have their engineering standards prepared in the foreign paradigm. Technical influences play a huge role in positioning the authenticity of students' practice, such as when unverified online resources are mixed with genuine ones; there is no one to direct students to the factually correct online resources except mainly peers. Sometimes the teacher's unwillingness to adopt mobile learning in a course did not create opportunity for the students to identify correct online sites or mobile Apps. Additional contributors to authenticity were their mobile tool usability, e.g. the user experience level, user attributes (e.g. resilience to finish a task, mobile tool competencies), and the kind of task each tool can accomplish (see Table 4.1). The type of tasks that can be done in the mobile tools, familiarity of the designated steps for the task (as task procedures vary), and complexity of tasks are influencing authenticity of the students' learning activities. The study showed that users' motivation and value lead them to accomplish their tasks' results. Motivation is enshrined within individual and social powers; some are self-motivated as they cannot find an alternative tool, and others are socially influenced. Social reasons are among the factors for motivating learners' adoption of m-learning (Sarrab et al., 2016).

The students introduced each other to what worked for them and which tool was used. They collectively shared their context-awareness of mobile tools on every course and task type they did.  This is in line with situated mobile engineering learning that has been described by Huang (2014), where students' practices focus on enhancing expertise and knowledge within an authentic context and culture (Naismith et al., 2004; Orr, 2010). To move on with their learning needs, the study found several techniques and approaches that the students created to evade limitations as shown in Table 4.2 and sub-section 4.2.2.2.2. Students usually create their learning approach or tactics to achieve their desired learning outcomes (Chung et al., 2017).

Strobel et al.'s (2013) view of authenticity is that there should be a proof of the students' perceived connection between their mobile tool's practices and what they believed can be accomplished (p.144). From the study, not all teachers supported the use of mobile learning in their courses and this shows the varied perceptions between the teachers and students.

In summary, the mainstay of authenticity is the student-centred perspective of mobile learning and its relevance to the practice of engineering and learning, and contributes to their skill improvement and provides a sound basis for fitting to industry (Herrington & Kervin, 2007). Students understood that what they are learning are real to the context and practice of engineering and they revealed situational issues surrounding it. Such understanding is the key to authentic learning for an engineering student (Zarei et al., 2017, p.3).

### 5.3.3 Forming own learning by customising activities

The terms that describe personalisation of mobile learning by the students are customisation (familiarisation of mobile learning), autonomy (self-independence in its use), and use of agency (supportive sources that give them choices to ease limitations). Personalisation has been described in two forms: adaptivity based on the student and adaptivity based on the student's learning surroundings (Kinshuk et al., 2009). For customisation of tools and activities described in sub-section 4.2.3, the study revealed their familiarisation of the operation of the mobile device they use and their knowledge of the platforms where they practice engineering tasks. Familiarisation added the power of knowledge or experience the students possess, for instance, it considers if there is a required training before using mobile tools or not, and if there is required training, how much training is required for a student to be able to use it to practice or learn. Insufficient knowledge of use is a hindrance to students' progress during the execution of engineering tasks, and that is why students stop their tasks and could not complete their jobs without assistance. The students' exposure level to similar tasks in that milieu conditions their customisation of mobile learning, and that helps the student's autonomy of use. Familiarisation of the technology in the performance of mobile learning over a task is the knowledge of what approach they need when using a particular software to do some tasks with a mobile device.

Agencies are the aiders to the development of mobile tool use skills. According to sub-section 4.2.3.2.4, a prominent agency the study found is use of social media and non-engineering related tasks the students do on their mobile devices. For instance, those two sources engage the students most often and contribute to strengthening their fingers-on-keypad manipulation competency.

In the extra-curricular activities engineering students do, sub-section 4.2.3.2.4 lists extra-curricular activities that are non-engineering tasks; those activities contribute to improving their mobile tool use skills as the students excel in doing them. In non-engineering activity, students are involved in part-time leisure over the mobile devices such as playing games, playing piano on a mobile phone and so on. Incorporating personalisation and collaboration in a mobile game-based learning can further assist students towards advancing their knowledge level (Troussas et al., 2020). The study found that some non-engineering tasks enhance the development of mobile engineering skills, examples are designing a clothing to sew and playing music using the piano in a mobile device.

In an effort to attain personalisation, the customisation of tools is achieved through resilience, persistence, changing patterns and the substitution of techniques and tools in use. From sub-sections 4.2.3.2.3.2 and 4.2.3.2.3.3 of this study, changing approaches which implies new practices in using an integrated range of mobile tools is inherent in the adoption of mobile learning (Conole et al., 2006). The learners who are using mobile tools adapt to situations based on what organises their activities and tasks; perceptions of usability, suitability, convenience, cost effectiveness, are key factors in ease of use (Kinshuk et al., 2011; Syvänen et al., 2005; Troussas et al., 2020).

Adaptivity arising from the surroundings of mobile learning tools revealed perceptions of what is customised. The limitations to associate with mobile tools are many; however, students are competent in evading difficulties and adopting mobile tools. Table 4.2 shows that such obvious areas of limitation that are surmountable include device screen size, low battery power, distractions, and inappropriate choice of tools (this is when a mobile user's low specification device results in incompatibility with high-capacity Apps).

For a continuum of engineering tasks that students do, there are specialised mobile features that are highly esteemed by the students and these are the processing speed of the device, touch-screen, storage size, memory, network detection and connectivity ability, power supply capacity, control and navigation, system support from the manufacturer, and added accessories such as a camera. These enumerated features must pass certain threshold to be sufficient to support mobile engineering education because of the kind of multifaceted tasks involved. The study found that certain courses and physical laboratory tools can be supported by mobile learning. It found what is achievable and not. During the interview, the participants listed forty-five (45) courses from beginning to the end of an undergraduate programme that can be supported and twenty-six (26) physical laboratory tools that can be supported by mobile technologies.

Assistance is the word used to describe these agencies that aid the students' choice of mobile tools as this study shows in sub-section 4.2.3.1.4. Sources of assistance are personal effort and someone's help.  The students showed transitioning on the levels of skill and knowledge acquisition, from beginner to expert level. Students' transitioning from introductory to expert level depends on what they do and the kind of effort they put in, and the transition's time frame varies depending on the individual, nature of task, and area of engineering – control, power, telecommunication, or electronics. In Huang (2014, p.13), transition is described as a scaffolding process, where student having a 'knowledgeable source' or 'more skilled peer' supports a struggling student and can 'share the cognitive load.' The amount of support the struggling student receives is gradually withdrawn (or faded out) as he becomes more skilful, and ultimately the student can then complete the task on his own (Chen et al., 2003). By transitioning, students need scaffolding to transition to a higher skill level. Furthermore, students learning practical activities assigned by teachers with mobile tools cannot exist in isolation without transitioning (Chen et al., 2002).

In summary, personalising mobile engineering learning emerges from adaptivity of the students and the mobile learning environment - device, tools and technology they use (Huang et al., 2015 ; Suresh & Hemabala, 2013). According to sub-sections, 4.2.2.2.3 and 4.2.3.3.2, the study found that the students created their own personalisation typically in relation to the setting, i.e., environment of learning, to suit their needs. In Zarei et al. (2018 ; 2017, p.3), mobile learning provides a lot of ways for engineering students to arrange their activities based on their needs, interests and possibilities.

### 5.3.4 Collaboration on mobile social media for learning purposes

Participation on mobile social networks involved conversation and data sharing amongst students. Conversation captured by the study revealed low activity whilst a student is on individual mobile learning. When the students get involved in long-range discussion, deep and dynamic chat, they develop high levels of activity, evinced by capacity of messages as shown in sub-sections 4.2.4.1.1 and 4.2.4.2.1, and Tables 4.5 and 4.8. One of the hindrances students experienced that concerns this issue is the absence of voice-over facility while working on tasks, as typing texts using the keypads consumes so much time, disrupts and needs the same hands used for solving tasks. Engineering students require hands-free collaborative platforms for exchange of conversation. Mobile tools required for practising engineering have been recommended to be hands-free (Monroy et al., 2016).

Data sharing involved in the online class activities involved texts, images, and videos. The three formats of data were used to varying degrees because of their varied cumbersomeness as revealed in sub-sections 4.2.2.1.2 and 4.2.2.2.1. Students on mobile social networks upload less videos because it costs so much and runs down their already paid internet subscription. Their texts (e.g. *.txt, *.xlsx, *.docx, *. rtf, *.log, *. Pdf), and images (e.g. png, jpeg, tiff, bmp, gif, psd, pdf, and html) were shared. However, the highest used text formats for students in that region are the free formats provided by the WPS office. Data formats play a role in creating interest and participation readiness. According to the study, the users of a mobile social media environment are more attracted to ‘video and image’ posts because it is quick to notice and interpret. Data and multimedia formats influence users in an online learning setting (Wilke & Magenheim, 2017).

According to sub-section 4.2.4.4.1, the study found that those reasons form the side attraction that allured more students’ participation on Facebook than on the class blog. Some users long to see entertaining effects on the sites, even though they have come to these social media sites for learning purposes or vice-versa (some users come to SNS for entertainments but then join the online learning activity). The site’s attractiveness, purpose of the users, rich content, and external influences such as accessibility easiness, contribute to the capacity of messages transferred amongst the students on the SNS; as the results show, the highest cluster formed considering both SNS holds a maximum of 23-online users and it was on Facebook. Rich content is required for an interactive mobile learning (Park et al., 2015). Also, the study found that engagement in a collaborative learning setting may not be limited to a specific number of online members if it is engineering but on the online users’ perception of social presence and satisfaction. The study contradicts Hamann et al.'s (2012) position that the best number that constitutes perfect collaboration is large, and Lowry et al.'s (2006) position suggest a small size. The study found more information exchanged in more than 3-member clusters as shown in Table 4.8; however, it was heightened by non-class members on the SNS, as the students revealed high learning impact such as new skills that they derived from non-class members who joined them in an online collaboration. Mobile social space accounts for possible learning and skills acquisition (Kekwaletswe & Ng'ambi, 2006, p.3). The results of number of messages and percentage participation in Table 4.8 showed that collaborative learning can exist beyond a specified number. Collaboration in the mobile environment contains learning processes and is promoted by social interaction (Huang, 2014, p.10). The platform that brings all the students together is the SNS, as they cannot build a network anywhere except on a social place. Interaction goes with learning in a computer-facilitated environment; mobile social learning is totally dependent on interactions in SNS when mobile devices are used (Naismith et al., 2004).

In summary, collaborative learning is supported by the mobile learning environment, students construct their knowledge willingly in different ways such as through interactions on social media. However, this is attained constructively as it contributes to the students' use of mobile technologies in acquiring knowledge and skill (Zarei et al., 2017, p.3). From this study, collaborative learning in a mobile social space is found to depend on sociability, users' attributes and philosophy, facilities (site, contents, hardware), tasks, and external users - teacher and online non-class members (Wilke & Magenheim, 2017). The SNS has strong tools to support engineering students for knowledge and expertise, especially when they engage in problem-based tasks in mobile learning (Moore et al., 2011).

### 5.4 Contribution of Research to Theory

Most research into m-learning adoption in engineering disciplines focused on abating the technical issues that constitute the major drawbacks of m-learning (De La Iglesia et al., 2015; Ma et al., 2016; Meolic & Dogŝa, 2014; Palmer & Hall, 2008). Little is mentioned on how interface issues affect learning or their influence on learning and how learning can be managed; however, investigating the actual learning that occurs in m-learning is useful in improving engineering curriculum development (Vate-U-Lan, 2008). This study has provided deep understanding of how to manage most interface and technical challenges associated with mobile engineering learning. In sub-sections 4.2.3.2.1.1 and 4.2.3.2.1.2, it showed in the context of EE engineering where different issues are surmountable and how to cope with tough limitations of mobile tools employed in practical engineering by elucidating locations where limitations are and how to overcome them.

That engineering students use mobile learning is not doubtful, but there is diminutive empirical evidence on how students use mobile tools for learning processes in engineering (Schuster et al., 2016, p.315). The overall results of the study emerged totally from an engineering milieu.

Furthermore, in most studies where perceptions and interactions of engineering students were evaluated, and multi-platforms were not used, such as in Chang et al. (2017), Cheng et al. (2016), Chung et al. (2017), Heo et al. (2018), Jiang et al. (2018), and Schuster et al. (2016). There is a myriad opportunity for knowledge building through interaction and collaboration using many virtual platforms (Pearce et al., 2012). However, these results that answered the four research questions provided a general understanding of effectiveness, and appropriation of m-Learning in engineering that will create meaningful learning that is required across the four extensive virtual platforms. And that was identified as lacking in engineering by Broadbent and McCann (2016). This study contradicts Sun et al. (2017) who found more interaction on the portal than the SNS, though the difference is that the latter happened in blended learning and this study, i.e. my research occurred in a solely mobile setting.

Also, studying mobile learning effectiveness in multi-platforms is incomplete without examining interactions (Moreno & Mayer, 2007), as well as perceptions (Gezgin et al., 2018). So, in line with this, this study found the students' interactions in the mobile social environment in addition to discovering mobile learning's efficacy, fulfilment, and usability.

In emerging mobile learning environments in engineering, this study has contributed by revealing future directions for research that will improve learning of skills and knowledge.

### 5.5 Contribution of Research to the Theoretical Framework

Many scholars have measured mobile learning using socio-cultural theory; however, the pedagogical framework developed by Kearney et al. (2012) adopted here has not been used previously with respect to engineering education. And by using Kearney et al.'s (2012) model, it revealed and added deep knowledge to the components of the three main frames of the model - authenticity, personalisation, and collaboration.

### 5.5.1 Authenticity

In authenticity, the study revealed the task, factual and process levels of authenticity within the frame of situatedness and contextualisation. According to Kearney et al.'s (2012) framework, authenticity appears in three levels, namely task, factual and process (p.9) (see Table 5.1). Task authenticity discusses the extent to which tasks are genuine and connected to real-world practice. Factual authenticity discusses how particular details of a task (e.g. standards), must be evident in a task process and are similar to the real-world, while a process level discusses how a learner's practices and procedures in execution of tasks conform to the ways they are used in real-world practices (Kearney et al., 2012). This study found factual levels to be low because of various contributors of which one is standardisation of engineering over the contents and tools.

The tasks students do, conform with real-world practice and fall within the specific area of engineering. For instance, in the electronics option, the simulation of programmable logic circuits was achieved, and results are like those they would obtain in real-world engineering. Factual and process authenticity levels varied accordingly because of those factors; this study found authenticity to be dependent upon such factors as mobile user's attributes: experience, familiarisation with tools in use, technical influence, and social effects. Various steps are followed by students to arrive at task completion. The study has added to the framework by indicating that levels of authenticity can help explain the mobile learners' actions within the milieu of situatedness and contextualisation. In Table 5.1, it shows what the students' engineering activities were with respect to three elements of scale of authenticity. Where there is authenticity, it is marked as high and where there is not always authenticity, it is low.

To generate Table 5.1, I returned to the interview data to review their engineering activities and counted those they claimed were authentic and those that they said were not authentic, for each practice. All the engineering activities that the students did fell into three categories - factual, process or task. For instance, the students stated that during an engineering practice of circuit design, every student usually adopts different techniques because of the diverse set of tools that each student uses, but that they will all arrive at the same authentic results. This is interpreted as low factual and low process authenticity, but task authenticity is high.

| **Scale** | | **Authenticity** | |
|---|---|---|---|
| | **Elements of Scale** | Situatedness | Contextualisation |
| **Levels of authenticity** | Factual | Low | Low |
| | Process | Low | Low |
| | Task | High (tallies with real-world practice) | High (tallies with engineering context area) |

Table 5.1 Outcome of study showing the situatedness and contextualisation with respect to authenticity levels.

The study revealed two elements of the models of authentic learning environments, it used the individualistic (described as a simulation model), and collaborative (described as a participation model) level. From this study, practices like simulation, testing, designing, etc. are accomplished mainly at an individualistic level. The failure of Kearney et al.’s (2012) simulation model is that in engineering there is more to consider because of the diverse nature of engineering tasks, for instance, a group-based design project.

### 5.5.2 Personalisation

In terms of personalisation, the study revealed that students have either internally or externally sourced agency. Self-motivation, self-developed tactics, self-efficacy, familiarisation with devices and device control skills are their internally generated agencies. External agency is low (there are few options that aid them in using mobile learning that are not created by themselves) as it manifests mainly in the SNS. The study found that the most externally sourced agency used in mobile learning is a networking place.

| **Scale** | **Personalisation** | |
|---|---|---|
| **Elements of Scale** | Agency | Customisation |
| | Low (Externally generated) | Low (Transitions except for high-capacity mobile Apps) |
| | Medium (Except on SNS where it is high) | Medium (Assistance) |
| | High (Internally generated) | High (Technical and user-related) |

Table 5.2 Outcome of study showing the agency and customisation.

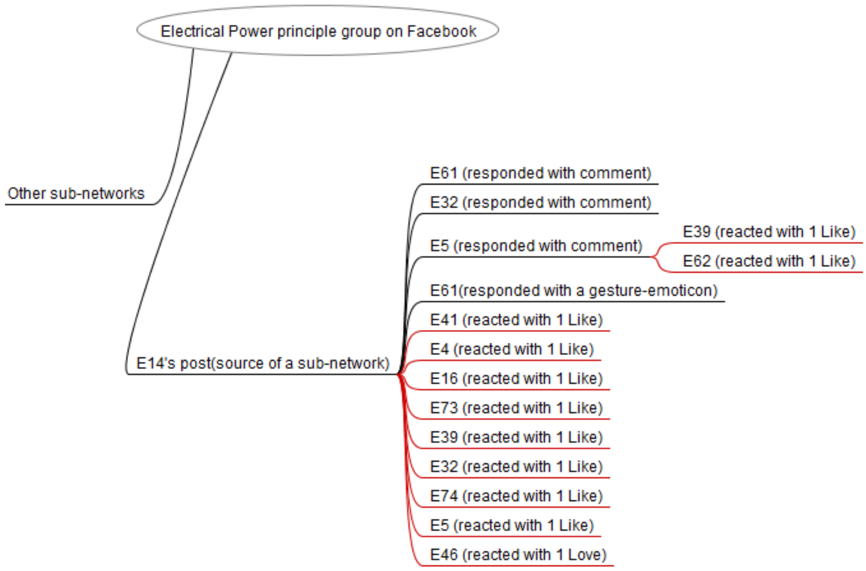
To generate Table 5.2, I returned to the interview data to review their engineering activities and review their agencies, those tasks where the students are helped, and the range of help they could receive, and those where they do not need help and could do the tasks by themselves. After counting, I scaled them, for those tasks where there is the widest range of help available I recorded as high, and where it is not it is low, and where it is moderate it is called medium customisation. For instance, the students stated that during an engineering activity or practice, the agency is basically individualised (internally generated) as they showed that they adopt self-help tactics in navigating limitations and external agency is low except when they practice with the SNS. And for that, I listed internal agency as high and external agency as low, and SNS's agency as medium. The sources that aid the student in customising activities are reviewed from the interview data, counted, scaled, and become rated as high, medium or low.

Customisation depended so much on the user and technical attributes; sophisticated Apps require more effort for all the platforms according to the students' reports. Easy tools require moderate or little assistance. Rich mobile-based tools can enhance students' learning progress, or as a learning activity driver, increasing their higher order thinking skills. For example, multimedia technology and design students reported that a daily mobile-based application helps them to revise theories related to their courses and keep track of their progress (Andreatos, 2012).

### 5.5.3 Collaboration

In collaboration, this study revealed from a socio-cultural perspective that the students are poised to transmit high numbers of texts, cluster on more interactive media such as video content, and participate highly on SNS. This is based on the kind of mobile devices they possess, technical or social challenges such as connectivity issues, and high data costs on video formats. Attractiveness of content plays a role in promoting high performance even though only a few videos were used by the students. There are ties and breaks among sub-networks, which is the connection, disconnection, and re-connection of members of sub-networks; that is what transcends during the online SNS discussions. The portion of disconnection and re-connection, a kind of push (send/post a message) and pull (receive posted message), depicts when a student joins a discussion or leaves a discussion. From sub-section 4.2.4.4.1, major activators of push and pull are rich content, presence of a smart student, external motivation (i.e., non-class members), and personal interests. The external motivation is evident by the cluster of ties that run across several nodes in Figure 4.10 compared to Figure 4.8 where there are fewer clusters of ties.

Attainment of stability or a cohesive sub-network (a group of discussants within the entire SNS network) is when pull and push stabilise, and learning is exhaustive. The SNS analysis in this study focused only on first to sixth week discussions; however, to understand the nature of network stability and how it contributes to learning, an extension of the network to the 13th week of discussion on Facebook can be suitably used to illustrate network stability and its influence on leaning. An extraction of the Facebook discussion that happened on the 13th week is shown in Appendix Five and its network diagrams of conversation and structure are shown in Figure 5.1. The diagrams of Figure 5.1 were not taken from the SNS structures discussed in Chapter Four, but they are directly taken from the Facebook page titled *Electrical Power Principle Group*, (https://www.facebook.com/groups/2803539939675118/). The purpose of building the diagram directly from the Facebook page is to elucidate stability of network and its influence on learning. The attraction and repulsion generate structural groups that are stable over time (Stadtfeld et al., 2020, p.132).




(a). Conversation (above), (b) Structure of Conversation (below)

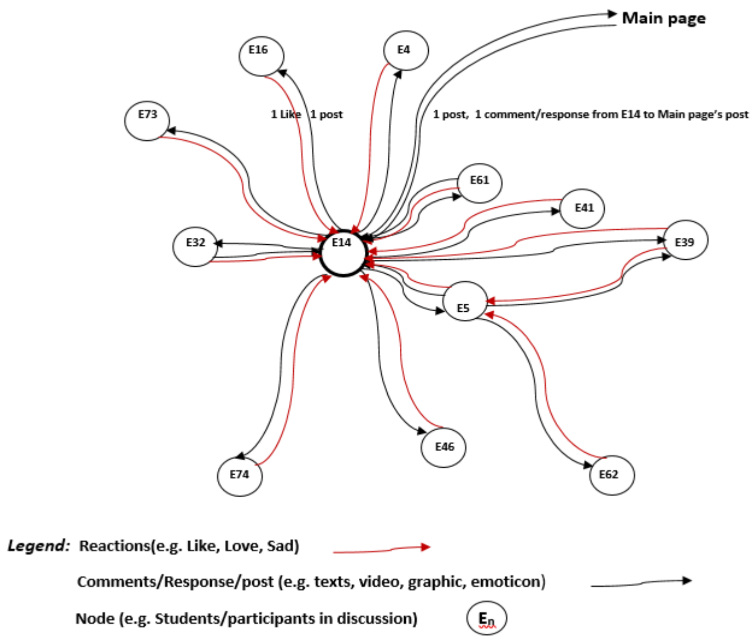



Figure 5.1 A fraction of the entire network showing the structural form of pull-and-push action of nodes in a sub-network by the communication exchange.

(see the SNS's discussion thread that bore the above network structure in Appendix Five - Extract of Discussion Thread).

In this study, apart from the teacher-led sub-network, which is the largest structure, there were two prominent sub-networks with each covering over twenty members (nodes), with other nodes involved in a push-pull phenomenon. In Figure 5.1(b), a portion of the entire network is shown with E14 as originator; student E39 unintentionally formed a loop with E5 and E14 (i.e. source of information) due to push-pull of information (i.e. knowledge), and similar effects occurred across the larger (main) network. Those structures retained their shape (i.e. knowledge is formed/gained) or improved if members continue to exchange information but cannot remove a tie or node from the structure that has already been formed during communication. For that kind of information exchange, for example, see Chung et al. (2017, p.3239). Stable structures can be momentary or can last longer depending on how engaging their interactions are. Explaining the nature of collaboration and evidence of knowledge transfers in this perspective, above, are missing in Kearney et al.'s (2012) model.

However, the shortcoming of using the structural forms to explain the pedagogical perspective of socio-cultural theory is that it cannot reveal or explain the level of learning a student has acquired unless those network nodes (participants) are interviewed or examined.

Notwithstanding, in a SNS learning environment, the structure offers insight into the management of multimedia resources and provides a way for manipulative interactive objects based on the combination of objects such as: videos; images; texts; and interactive mechanisms (Claros et al., 2016, p.192). This has provided a basis to discover students' (i.e. learners') tendencies towards the SNS content, the media format, etc. such as video, texts, audio, and graphics and the study showed how each influences data sharing, learning engagement, and conversation. Voice conversation which is an element of collaboration is drastically low in an engineering learning setting especially during task practice.

| **Scale** | **Collaboration** | |
|---|---|---|
| **Elements of Scale** | Conversation | Data sharing |
| | Low (individualised learning) | Low (size of file in non-interactive media) |
| | Medium (audio) | Medium (video, graphics) |
| | High (texts) (group learning) | High (texts) (size of files on interactive media) |

Table 5.3 Outcome of study showing the conversation and data sharing

To generate Table 5.3, I returned to the interview data to review their engineering activities and reviewed where the students mentioned they collaborated, those tasks where the students could and could not collaborate.

After counting, I scaled them, for those tasks where they could collaborate, i.e., share data and converse, I recorded it as high, and where it is not it is low, and where it is moderate it is called medium. The activities on collaboration are reviewed from the interview data, counted, scaled, and become rated as high, medium, or low. For instance, the data sharing and conversation is low for non-interactive media and individualised learning. It is understandable that it is low because the students stated that internet costs deprive them of using online mobile learning and hence hindered transfer of more data.

Furthermore, the study found the commensurate level of collaboration at which the students satisfactorily learned in their connectedness in the SNS facilitated by mobile devices (Kearney et al., 2012). The level of network generated when the students are connected creates shared, socially interactive environments such that students could readily communicate multi-modally among themselves (Kearney et al., 2012, p.10).

This study investigated the meso-level, the students' experience, and their exchange of messages. It undertook the meso-level investigation through an analysis of the structures of interactions that existed between discussant groups in the mobile social environments.

In addition to studying collaboration by examining interactions, the study examined personalisation and authenticity in engineering and found where and when engineering practices could be possible. And all of them are merged into one diagram as shown in Figure 5.2, where online and offline platforms lie within the Time and Space zone and this zone covers the range of authenticity, personalisation, and collaboration. All engineering practices, courses, and laboratories are covered within the six constructs of authenticity, personalisation, and collaboration. And that indicates that the constructs of authenticity, personalisation, and collaboration are factors in the success of the course, practice, and laboratory. This is evidenced by the students' reports in sub-sections 4.2.2, 4.2.3, and 4.2.4, where the students showed the authenticity of engineering practices, the customisation of learning activities, and collaboration for learning purposes.

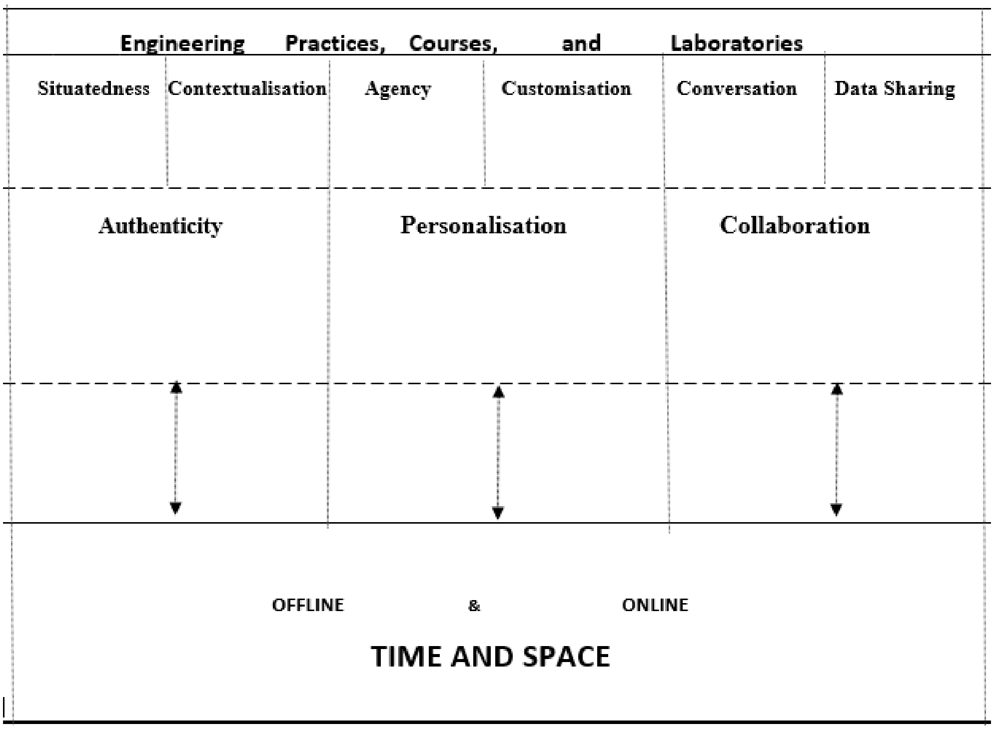



Figure 5.2 The result of the study, a developed model adapted from Kearney et al.'s (2012) pedagogical framework.

In summary, according to Kearney et al. (2012, p.14), the framework is flexible, and it recommends further research that can account for the learners' specific characteristics and needs, the environments in which the learning could potentially take place and the preferences associated therein. This study thereby investigated the space and time that embrace offline and online as fundamental environments, and the preferences for engineering learning and practice are studied. The study also suggests that the learners' choices and preferences shape the three main frames -authenticity, personalisation, and collaboration.

### 5.6 Implications of Findings for Teaching Practice

A learning pathway is a process or student's learning experience that is socio-culturally shaped. The terminology emerged from this research through the word "scholarship", implying regular ways that learning has changed over the years resulting from social imperatives such as economy, technology, institution, and so on (McKinney, 2013, pp.1-12). In this context, studying engineering in a debilitated educational setting is tough as described by Kehinde et al. (2011), joined with customising efforts the students use to lead their tasks towards real-world authenticity.

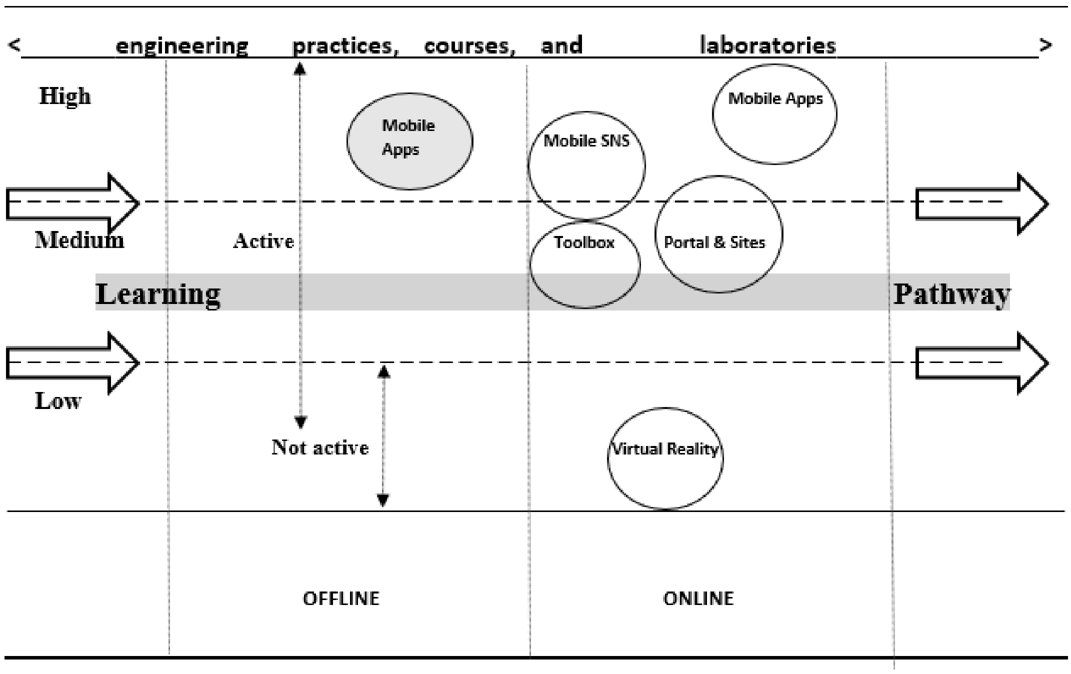



Figure 5.3 Research findings

In Figure 5.3, there are three zones of mobile learning usage as found by this study, the high level is the top-most level, depicting what they use regularly, and where they derive what they need, where they frequent, and where it is easy to access. The medium level is moderately used platforms, and the low-level zone is the not-regularly used platforms, e.g., virtual worlds. They have experienced virtualisation but have not been using it for their daily tasks, laboratory practices, and experiments. In Figure 5.3, active and not-active layers are the always used and not used platforms.

This result shows where mobile learning should be located; it is in the offline zone and it is mostly relying on mobile Apps, according to Figure 5.3. The offline zone is where circumstances have forced them to operate. Mobile learners are conditioned by circumstances around them, leading to BYOD

(Ally & Tsinakos, 2012, p.100). This implies that engineering education in this context must develop curriculum that will be delivered mainly through mobile offline or stand-alone applications. It does not imply online Apps and websites are not useful. Figure 5.3 shows that virtual reality is scarcely used, even though students found it useful for further practices that can be hands-free. The results show that engineering course materials, lectures, tasks, assignment, simulations, drawings, circuitry work, project designs, workshop, and mathematical analysis should endeavour to be mounted on non-internet-based applications. This study revealed a wide range of applications that are independent of the internet for use. The limitations challenging the use of mobile tools in engineering learning as discussed in the previous chapter are reasons that explain why students adopted this sort of unique mobile learning adoption.

In Figure 5.4, the elements of Kearney et al.'s (2012) framework are covering the developed model to show how engineering practice leads to authenticity (i.e. situated and contextual realities), through the pathway of collaborating and customising practices by using agencies, already-made knowledge acquired in pre-engineering years, outside school learning, knowledge shared from peers, etc., leading towards graduation as a skilled engineer. The interpretation of Figure 5.4 is a summary of the research findings, and embedding the findings on the four segments of the mobile pedagical framework is used to represent that authenticity, personalisation, collaboration, and time and space are the lenses through which someone can understand mobile engineering practice and education.

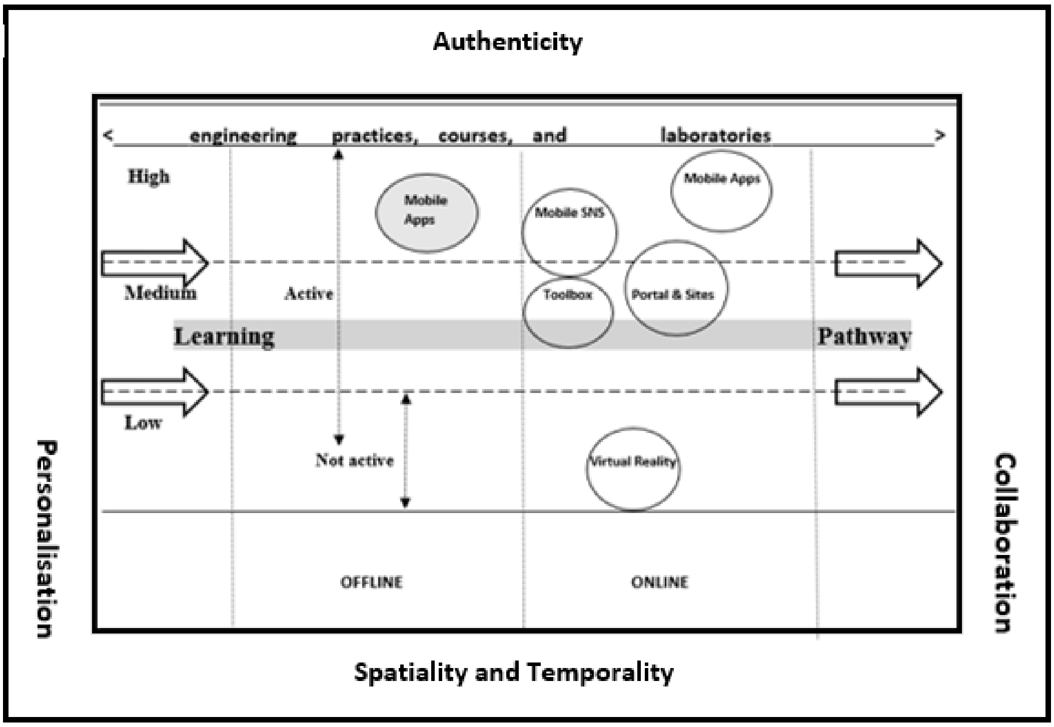



Figure 5.4 Proposed model for FUOYE's m-learning developed from the pedagogical framework (the grey shaded circle is the location of their mobile learning)

## 5.7 Recommendation for Policy in the Use of Mobile Technologies in Engineering Education in Academic Institutions

This study recommends that standardisation can play a role in controlling and appropriating resources that students access, and use. Issues about standardisation of the physical laboratory may be affecting the adoption of online laboratories. And the mobile learning resources that are predominantly accessible in the non-local standards will not make learning difficult when students try to appropriate virtual activities to real-world practice. This is because learning on mobile platforms in an unfamiliar standard may deny authenticity of tasks. The local engineering standardisation authority, Nigerian University Commission, and Nigerian Communication Commission can work collectively to parameterise use of mobile engineering contents, preparing and scrutinising them to make it ready for undergraduate education. In addition to the need for proper coordination of mobile learning in engineering whereby courses and laboratories are designated to specific mobile tools, the study found its relevance in dealing with unverified resources or resources under trial, in the cloud, that students sometimes erroneously access and use in their work, and that may compromise a task's authenticity.

### 5.8 Recommendations for Engineering Teaching Practice

The findings revealed two suggestions to uphold mobile engineering learning, in FUOYE based on the university's peculiarities and in the other institutions in sub-Saharan Africa based on commonalities in socio-cultural behaviours towards education (Shizha, 2014, p.1871).

#### 5.8.1 In FUOYE

Implementing mobile learning can help sustain better engineering expertise in a university that has insufficient laboratory equipment and prepares undergraduate students capable of fitting into the industrial sector with adequate knowledge and skills. And for that to be possible, the following recommendations were gathered.

(1.) Teachers should investigate the platform or software that students can easily use and is course-compatible and deploy their course work in it to enable students to carry out personal study anywhere, anytime. More students are using medium and lower versions of mobile devices, especially cellphones. Therefore, adopting m-learning in engineering will suit all students when compatibility is prioritised.

(2.) Teachers should not believe that distraction is a barrier to learning with mobile devices because students can use mobile tools to learn and practice.

(3.) Provision of 'Try it Yourself' is required on all engineering Apps. A section of the software's user interface, probably on the menu where a learner can do some exercises and verify his competencies before skipping that session.

(4.) Large mobile Apps may be better segmented, if possible portioned into two or three, in such a way that a moderate mobile device can run it perfectly without rolling or crawling due to lower versions of a system's specification of the mobile device. Most software is demanding high or sophisticated smart devices to run them and not all the students can afford them.

(5.) Question and answer sites should be provided for various practices in engineering.

(6.) Universities should promote awareness of mobile learning among teachers since almost every student possesses a mobile device.

(7.) Adoption of mobile learning is to be encouraged in the developing countries' universities because many of their laboratories are not adequate with equipment that can embrace the engineering training every student requires before graduation.

(8.) Augmenting the theoretical concepts with imagery and video is highly recommended by engineering students as they claim that it drives ideas and meaning faster than ordinary texts or scripts they see in textbooks.

(9.) Virtual world devices can greatly support training during workshop practices since there are insufficient machines to serve all the students. The study gathered the students' experience with virtual reality tools during their SIWES. Examples of VR devices recommended for students are HTC[14] Guess II, and the Pico device; both are integrable with mobile tools for EE engineering education. High screen resolution, versatile control and robotic ability is believed to contribute to this emerging trend in the tool students will work with.

### 5.8.2 In other institutions in the sub-Saharan African region

Sub-Saharan African has poor investment in educational development (Oketch, 2016). There are many institutions offering engineering education at undergraduate level in this region, and many have technology-related issues (Adeyemo, 2000). Students have been operating by individual choice as institutions in this region have not developed a mobile learning template. Therefore, this study reveals recommendations for institutions intending to operate mobile learning.

[14] https://www.htc.com/us/

1. University authorities should encourage mobile learning and use it as a tool for supporting student learning.

2. Universities should incorporate mobile learning into their curriculum and equip the respective ICT units to provide support for on-campus mobile learning. The bandwidth provided by the ICT should be capable of carrying several mobile users without getting over-burdened. And they should provide strong mobile Wi-fi networks for streaming during remote laboratories.

3. The mobile library and repositories should be equipped and prepared in an accessible way to avoid complaints of incompatibilities or inaccessibility of software and hardware. Content should be deliverable across all types of device and platforms.

4. Technologists should be trained on mobile learning. Training on mobile Apps used for teaching and learning in engineering is recommended for all teachers and technologists.

**5.9 Limitations and Weaknesses**

As this research is studying electrical and electronic engineering students' m-learning, there is a possibility that participants may not have all-encompassing experience of all elements of mobile learning adoption in every engineering course.  However, they do share knowledge based on previous classes, laboratory practical or self-practice on simulation, control, design, etc. I adopted strict measures in selecting the knowledgeable few with experience of m-learning and electrical and electronic engineering.

Secondly, investigating undergraduate engineering skill through mobile learning, in this context, may not be universal across all sub-Saharan African universities. There may be an exception, but the bane of poor engineering skills is inherently a societal issue seeking an intervention, and it is still striking across the region, as disclosed by their local authorities.

Thirdly, I selected social network analysis as the method for examining social learning in the SNS. Errors that usually occur are making a missing or double count of a node or tie especially during the stage of building datasets before they are exported to the SNA software (Borgatti & Molina, 2003). I made extreme effort to avoid re-count of nodes or ties. However, with respect to SNA's error effect to the overall research result, it may be insignificant since this portion contributes one of the four research questions of the entire study. SNA may not reveal all pedagogical preponderances occurring in a social site, but it provides an insight into understanding the way learning occurred by showing which students participated in discussion and their percentage of contributed ideas.

### 5.9.1 Reflections on number of participants

The number of participants was sufficient for the purposes of this case study as the number falls within the recommended rule on size discussed by case study scholars and experts in sub-section 3.4.2. Results may or may not have been different if I had used: more participants, examined more universities rather than using a single site of research, or had participants from a different area of engineering. However, the area of engineering selected for this research was chosen as it is one that all engineering students do before graduation; also universities' engineering curricula are administered by one local authority and policy. And increasing the number of students would not have made a substantial difference because this is a field of learning where students collaboratively learn and share experience. The target was to recruit students with industrial experience and who have used mobile engineering learning for a long time. And that was the reason only fourth- and fifth-year students were invited as their industrial experience was highly relevant. I carefully selected students with adequate knowledge and experience of mobile engineering learning.

### 5.9.2 Definitions and terminologies

Many terms have been used to describe mobile engineering learning, in which various mobile devices were either excluded or included as part of the devices used for learning in this context. Here, I excluded the laptop as a mobile device just as some engineering literature did not recognise it as a mobile device (Ashfaq & Sirshar, 2018; Choi et al., 2014, Eneje, 2020, p.4). This study ensured that all information used was only from mobile technologies. The definition of mobile engineering learning that is upheld is the way of learning undergraduate engineering programmes with mobile technologies (tools, devices, and sites) anywhere and anytime.

## 5.10 Suggestions for Further Research

Four areas have been identified where further research could be pursued. Firstly, most experiences gathered are from mobile technologies use, excluding use of VR in learning. Implementing a VR mobile integrated practice may be helpful in understanding hands-free mobile learning. Performing empirical laboratory work using VR on various kinds of tasks would be required to confirm the possibility of using such a hands-free tool in engineering.

Secondly, educational policy should be investigated in this university and other universities, with a focus on mobile engineering learning. It will be helpful to investigate challenges that hamper implementation of policies on mobile learning.

Thirdly, further research may produce possible pathways for eradicating the accessibility challenges of mobile learning.

Finally, this study found that research is highly required in figuring out how to produce a high-quality, interactive, feedback system on the practices students engage in on their mobile applications.

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## Appendix One: Recruiting Participants

Survey Questions used to recruit participants; **93** were screened, and the selected participants were also confirmed of their true knowledge of mobile learning. Go to https://lancasteruni.eu.qualtrics.com/Q/EditSection/Blocks?SurveyID=SV_6Xa8uh2rLirrmEl

Qu.1. I am an undergraduate student of Federal University, Oye-Ekiti, Ekiti state, Nigeria?

- Yes
- No

Qu.2. Your gender

- Male
- Female

Qu.3. Age

- less than 18 years
- between 18 and 39 years
- Above 39 years

Qu.4. When are you filling this form?

- Last week of October, 2020
- First week of November, 2020
- Second week of November, 2020
- Third week of November, 2020

- Fourth week of November, 2020

Qu.5. Your level of study in Federal University, Oye-Ekiti, Ekiti, Nigeria?

- 400 level student
- 500 level student

Qu.6. Are you an Electrical and Electronic Engineering student?

- Yes
- No

Qu.7. If you an Electrical and Electronic Engineering student, Do you know your choice/field ( now or future),

- Yes
- No
- Maybe

Qu.8. Do you know what is Mobile Learning and have use it? If the answer is YES, move to the next/last question.
*Clue: Mobile learning is the use of portable electronic devices to learn anywhere anytime, apart from laptop*. It is the use of mobile device to learn, practice, document or do anything that pertains to your engineering learning either in school or outside school, with or without internet.
If your experience is YES, please, SELECT 'Yes' so that you will participate in the interview questions. ( YES/ NO ). How can I reach you?. Write down your cellular number(s) and email address here in the next question

- Yes
- No

- Maybe

Qu.9. If your answer to the last question, i.e. Qu.8 is YES, How can I reach you? Send me your contact details, Cellular number/email address to my email, it is --> s.eneje@lancaster.ac.uk?

## Appendix Two: Semi- Structured Interview and SNA Questions

Semi structured interview questions:

Note: These questions will be held in two interview sessions for accuracy of facts.
*(Note: For the sake of this research`s objective, Please, we DO NOT consider high cost of internet data, cost of mobile device or electricity supply as hindrances. We are considering adoption of mobile tool in normal situation. For every question, I will appreciate if you can provide real-life examples. Also, the constructs of the theoretical framework to be used in this research are the headings that cover every question, e.g. Space and Time, Personalisation, etc )*
………………………………………………………………………………………………………………

### Demographic Question

1. Participant' s initial ………………………………………………………….………
2. Gender: Male / Female
3. Age: (A) 0 – 18 yrs (b) 18 – 39 yrs (c ) 40 – above yrs
4. Date and Time : …………………………………..(dd/mm/yyyy),………………….(hh:mm)
5. Level of study (400 or 500), ………………………………………………..
6. Your choice/field of Electrical and Electronic engineering ……………………………………………………….
7. Do you know what is Mobile Learning? If he/she answered NO, I will explain the meaning. If the answer is YES, I will move to the next question. *Clue: Mobile learning is the use of portable electronic devices to learn anywhere anytime, apart from laptop*.

### SPACE and TIME

1. Where have you used mobile learning or experience it, when and how long ? For instance,
   - A. Use it while surfing information and submitting your works through the student portals ( Moodle, Blackboard, etc.),
   - B. Use it for learning publicly via video uploaded to video sites and social media channels (e.g YouTube, CORE-Materials, Coursera, FutureLearn, Jorum, and MIT OpenCourseWare, Facebook, Class Blog, etc.)
   - C. Use of Student/School Portals(i.e.Learning Management Sites or web portals) to moderate online engineering learning, resources will be disseminated or used in massive open online courses (MOOCs).
   - D. Use of mobile and desktop applications e.g. Arduino, AutoCAD, Solidworks, , Python, Simulink, PCdroid, etc, to harness simulations and practice.
   - E. Use of a toolbox and virtual material laboratories ( e.g R, AutoCAD,etc )
   - F. Use of mobile device to remotely operate other tool/equipment either in the Lab. or Robotic.

2. What is your perception on how each one of the above (#2 A-F) are impacted, in the way you learn, your academics and/or skills, when used on the mobile device?
3. How do you view mobile devices as an influencing/persuasive tool that is part of every student`s academic life? And in what areas of activities/interactions do the mobile devices play roles?
4. Do you have any of those platforms that you have used that can run (a) internet-based, (b) Stand-alone? (c) both? if yes, which one? Describe the situations properly. And what kind of mobile device did you use then?
5. Where do you normally use the mobile device to learn, what kind of environment do you use it more, in school or outside school environment? Is it on a sole use, social media, class discussions, SMS chats with colleagues, connected to a virtual school, connected to a server, connected to a toolbox, on the mobile app, most of the time?
6. Where do you do the mobile learning more often, in school or outside school environment? Explain where and what kind of task you did?
7. Considering at all the previous questions #1 to 6, Suppose you work in groups or network with your peers, what are your experiences like, any hindrances and benefits, do you have different answers to #1 to 6?

## AUTHENTICITY

8. In what ways does the use of mobile learning impact how you learn engineering stuffs and real practice? From your opinion as an engineer-to-be, what do you think should be done to improve mobile devices so that they can be capable of doing a good number of tasks in your own field of electrical and electronic engineering?
9. What motivates you to use of mobile devices in supporting your learning? Would you say that you have learned something since you have ben using it? Has it added some value to you, if yes, what are the values you derived from it, skill-wise or academic?
10. Should a policy mandates that mobile devices especially cellphones must not be used by students any more on campus, do you think it will affect the skills in engineering students (oppose or support)? Do you think that there are truly skills you or your peers learn by using those devices?
11. How have the Mobile learning creativities conditioned the type of resources you select for your studies (sharing ideas, asking questions to someone, demonstrating a stuff to your peer, simulations, testing, calibrating, measuring, designing, etc.), Do your actions/steps always comply with Manual’s procedures?
12. Do you face challenges understanding the applications or the stuffs you do in the mobile devices? If yes, what are they and how? Do you think you have achieved some level of engineering skills, knowledge based on your study, or general knowledge since you started using the m-learning? How do you optimise the outcomes of your tasks? Predict your analysis/get convinced you’ve done the real stuff? Do you have some logs(texts/video/graphics) to buttress your explanations?
13. Do you think that m-learning is suitable for the general learning environment of all fields of electrical and electronic engineering? Categorise the areas of electrical and electronic engineering to what kind of platforms, tasks, where, materials that maybe needed for its success. Explain with real examples?

14. Considering at all the previous questions #8 to 13, Suppose you work in groups or network with your peers, what are your experiences like, do you have different answers to #8 to 13?

## PERSONALISATION

15. Do all of those you have used require initial training/experience/knowledge or are they easy to use? Tell me those easy ones and hard-to-use ones? Why do you think those easy ones are easy and why do you think those tough ones are tough?
16. Did you have a self-decision to use mobile applications to support your learning or were you directed by someone? If not self, who?
17. What are your perceived obstacles that are facing the adoption of m-learning in the institution of higher learning, do you face issues with coping with contents appearing via your tools? And what your perceived benefits of it too? (consider when you are in classroom or Lab) What kind of engineering tasks were or were not accessible satisfactorily?
18. For learning stuffs in engineering, which of the mobile device and/or platforms do you think is the (a) learner-friendly (b) easiest content (c) most usable/ (d) most suitable in the kind of society where you live? And how does it impact your practical? Give reasons to support your claim?
19. Considering the technical limitations of mobile devices such as small screen size, low power supply, content issue, distraction, etc., how to you manage the device to help your personal activities when there are no other tools to use? What steps do you take?
20. What other things outside engineering are mobile tools useful for, to you or your field of engineering? In documenting, have you used the mobile tools to store your data/share data, can you share your experience?
21. Should there be an urgent need for mobile tools to be used for learning in engineering, what are the major mobile device features that are mandatory for all electrical and electronic engineering irrespective of field or course? And which tool could it be?
22. Can you list all the things you can do in an m-learning environment using the mobile device and those you cannot do, considering all areas of electrical and electronic engineering?
23. Were there things you weren`t/couldn`t do before with mobile device before in the past, but presently you can do them? What really happened? Did anyone introduced how to do some activities on the mobile device to you and what were the things you usually do before?
24. Considering at all the previous questions #15 to 23, Suppose you work in groups or network with your peers, what are your experiences like, do you have different answers to #15 to 23?

## The SNA Questions:

## COLLABORATION

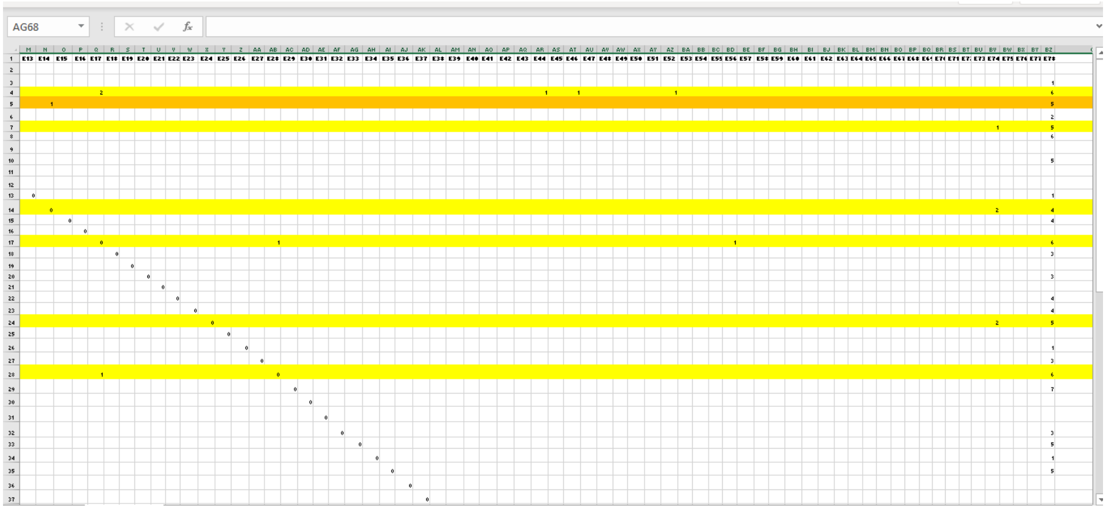
25. Measures of Interdependence on participation, engagement, and interaction (may not be limited to these since this segment is quantitative analysis using Social Network Analysis):
    (a). What pattern of interaction threads in the least collaborative group shows the teacher's importance in the discussion among the students?
    (b). What figures indicate the most collaborative groups
    (c ). Which of the learning group(s) is the most cooperating, most collaborating, most engaging, and interactive?
    (d ). How are the social structures, what explanations could identify why their study periods assumes such structures and ties?
    (e). How can social network structures be used to explain the conversational approach in learning?

## Appendix Three - A Sample of Thematic Analysis used in Qualitative Segment.

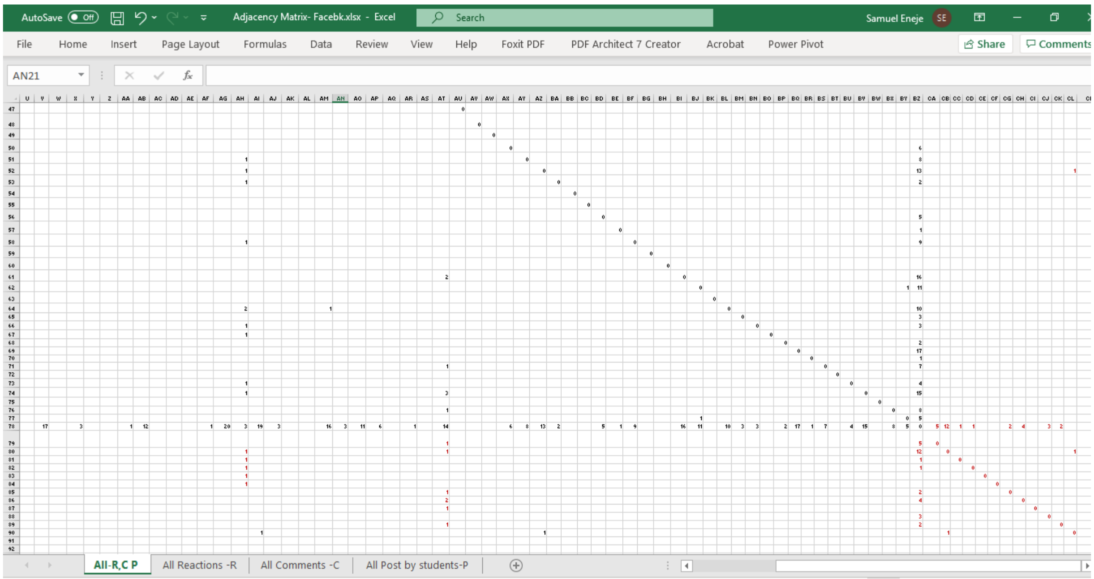
| s/n | Raw Data | 1st Order | 2nd Order | Result |
|---|---|---|---|---|
| A | Not easy for beginners especially in programming.<br><br>Using it on navigating the student's portal confuses in the beginning but normalises after few encounters. | (i)Toughness/Difficult | Dualized behaviour of m-learning.<br><br>[ (i), (ii),] | |
| | Easy for all on the website platforms. | (ii)All platform supported | | |
| | Has reduced stress of moving around with large devices. | (iii)Mobilised learning | | Users' perception: |
| | Makes accomplishing all students' tasks easier by putting them online. | (iv)Tasks Reliever/ re-solutioning | Aligned Technology<br><br>[ (iv), (v), (vi)] | |
| | Mobile devices and technologies have been effective in engineering learning.<br><br>Provides more room for other engineering Apps for learning. | (v)Alignment with engineering curriculum. | | |
| | Believes that modern technology drives learning. | (vi)Developing technologies | | |

# Appendix Four- Dataset Tables (Spreadsheets)

Blog



Facebook



## Appendix Five - Extract of a Discussion Thread used to Illustrate a Sub-Network Structure During Collaboration

Electrical Power Principle Group

[redacted] shared a post.
28 November 2019 ·

Y IS it rated like that

**Why Are Generators Rated In kVA Not In kW???**


Electrical Ride shared a post to the group: Electrical Engineering World.
28 November 2019 ·
Why?

9 · 4 comments

Like · Comment

[redacted]
Copper losses ($I^2R$) depends on current which passing through transformer winding while Iron losses or core losses or Insulation losses depends on Voltage. ... That's why the transformer rating may be expressed in VA or kVA, not in W or kW.
Like · Reply · 1 y · 2

[redacted]
Generators are rated in KVA not in KW because, it is the magnitude of the winding current that heats the winding and is the limiting factor.
The phase relationship between voltage and current (power factor) is not relevant in this heating effect.
Like · Reply · 1 y

[redacted]

Like · Reply · 1 y

[redacted]
The main factors manufacturers consider while designing electrical devices and appliances which provide electric power like transformer, UPS, alternators and generators,etc are load and power factor. As they don't know exactly what is power factor and ... See more
Like · Reply · 1 y