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A Framework for Evaluating the Usability of Mobile Learning Applications in Universities

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Abstract: *As the use of mobile devices overwhelmingly outpace that laptops and desktop computers today, high levels of usability of these mobile devices are a major supporting factor. The trend extends deeply into teaching and learning as mobile learning (a new form of electronic learning) takes shape, introducing an eminent aspect of mobility. Usability defines the aspects of quality in use of the software products; hence usability testing is a major concern in developing organizations for the success of product implementation and use. Most existing usability evaluation models were developed for desktop software development. Consequently, currently available models are not about mobile learning in particular, which also presents a gap that we attempted to fill.*
The researcher in this study developed a model that estimates usability as a function of aggregated usability influencing factors. The developed model combines important factors from other available models and encompasses most that support mobile learning to come up with a more comprehensive model. To evaluate the effectiveness of the developed model, a mobile learning prototype application was developed, tested and implemented alongside a task list for an objective study and survey questionnaire for a subjective study. The feedback from the experiment and survey was then used to assess and validate the prototype application in terms of high, average or low levels of usability using an advanced statistical tool. The results could be used as guidelines to developing organizations to produce more appropriate applications for mobile learning with high levels of usability.
Key Word*: Usability; Software Quality; Prototyping; Subjective test; mobile learning; mobility*

I. Introduction

The demand for learning anytime and from anywhere has specified the need for mobile learning (m-learning), acknowledging the use of mobile devices (laptops, personal device assistants, and smartphones) which are becoming more and more popular (Jung, 2014). Mobile phone attributes of both the hardware and software are the key aspects that enable their portability, performance and usability. The mobile learning context is extremely dynamic. Because of this, the applications of mobile learning can vary greatly according to the context and situations from basic to advanced education and other corporate learning settings; as well as from formal and or informal learning to classroom learning, distance learning, and field studies. Some of the software and mobile applications have been purpose-built for educational use but some of them are off-the shelf solutions originally intended for other uses like business use. Usability is context-sensitive. This means that software that can provide high levels of usability in one context can have low levels of usability in a different context. The application context

includes: the tasks executed with the software, the environment in which it is used, and the users that fulfill tasks with the software (Y. Park, 2011)

Mobility of the learner has not been catered for greatly as developers sometimes overlook the fact that users always will want to interact with such devices while on the move. Small screen sizes, limited connectivity, high power consumption rates and limited input and output modalities are just some of the issues that arise when designing for small, portable devices. And this limits mobility. Mobile learning exploits both handheld computers and mobile telephones (smartphones) and other devices that draw on the same set of functionalities but it is relatively immature in terms of both its technologies and its pedagogies, though it is developing rapidly. This draws on the theories and practices of pedagogies that are used in technology that enhances learning and others used in the classroom and the community. Many a times, developers do not consider the fact that users want to make use of these device applications anywhere they are (Harrison, et al, 2013). As users are constantly depending on these applications for their communication and other important services like news and sport update, weather reports, travel information and social activities, users take along their phones everywhere. Therefore, need arises for mobile applications to be usable by people as they change their locations. Users of mobile applications may be performing additional tasks, such as walking, while using their mobile devices unlike traditional desktop applications where user are stationed in same environment. (Harrison, et al, 2013).

The most currently implemented mobile learning platforms today include WordPress, Moodle and Blackboard apps. These applications (apps) are empowered by great features that help the users in the following ways; See courses at glance, connect with course participants, pull to refresh, the apps display in portrait or landscape view, whatever your screen resolution, View course activities and download materials for offline use. Also, they enable one to track progress from the device. Teachers can view site, course and personal notes about their students and add their own notes, Send and view private messages to colleagues and students from the Messages link in the side tab. You can view and upload to your private files, and so on. (Penny Johnson, 2015)

Any deficiencies exhibited by such an application can greatly hinder users from being efficient, effective, and productive include, an application that is difficult to use, a difficult-to-learn user interface, user interface that is difficult to remember how to reuse, learning content structure that is unclear; and a process workflow that is difficult to perform. The user interface has to be easy to use and effective and this helps users to focus on their learning goals, learning content, and activities instead of how the system works. One has to note that utilizing design guidelines is vital in developing learning systems. (Ali, A., Ouda, et al, 2012). When designing desktop computers and applications, many usability guidelines are used. However, these guidelines cannot be utilized to design and develop smartphones and mobile applications, and this is because they do not address the issues related to mobile phones and mobile phone applications and their current limitations. "There is a lack of good-quality usability guidelines for designing and developing mobile applications," (Ali, 2013).

II. Problem Statement

Mobile learning can be characterized by the ability to promote a strong interaction among teachers and learners, assuring greater motivation, convenience, collaboration and flexibility to the learning process. Mobile learning environments have emerged in this context as a way to support the m-learning initiatives. However, despite their relevance, there is no complete and well-defined set of requirements for such systems. Moreover, these applications come with usability limitations: There are Interactivity issues of mobile applications; difficulty in data input by the user plus limited data input methods and output limitations in terms of methods, media format support and application interfaces that are unattractive, hard to learn and navigate, with limited customization functionalities and missing features which present usability issues on the user and hence this hinders mobility. Moreover, alongside applications that depend on remote connection to the web servers which is neither convenient nor cost effective, most applications require costly supporting features and frequent upgrades without which they cannot work well or at all; Also, constant crashes, hanging and obsolescence of some mobile applications present concerns to the end user hence constraining and limiting use. Therefore, there has been a great need for quality in terms of usability in an effort to encourage use in learning and other productive activities, to reduce resource depletion, prevent waste and mitigate associated individual and societal impacts and risks. And this can be achieved through usability testing and adhering to the facts thereof by the developing companies. The researcher developed model to test a prototype

of an environment in a survey, results were analyzed and recommendations published as application development as guidelines.

III. Related Literature

Literature review is a way of evaluating and identifying the related studies and current practices relevant to the area of interest. Many researchers such as Hornbæk et al, (2012) have employed literature review as basis for their research work. The literature review for guidelines is done by reviewing research papers based on keywords "interface design", "mobile interface", "usability", "interface design for children", and "educational apps".

Learning analytics (LA) use static and dynamic information for real-time support of students' learning processes and optimization of learning environments (Ifenthaler, 2015). Besides its flexibility, the main advantages of LA are personalization and the real-time availability of data (Ifenthaler et al., 2014). Lecturers may use rich data for pedagogical decision-making, understand individual performance development of students, identify potential lack of students' capabilities or the need for curricular improvements (Mattingly et al., 2012).

With LA, both students and lecturers can reflect on and improve their communication skills. By capturing, analyzing and visualizing the available information about learning and teaching, lecturers are able to make more reliable predictions about their students' academic success (Macfadyen and Dawson, 2012; Mah and Ifenthaler, 2018).

Furthermore, students at risk can be identified and given support through personalized pedagogical interventions (Lockyer et al., 2013). Successful applications of LA at universities are, for example, Course Signals at Purdue University, aiming to identify students at risk using an approach similar to a traffic light system (green – no risk, yellow – potential risk, red – risky). Students and lecturers can identify needs for action to improve their learning situation. Furthermore, lecturers are able to intervene and help early (Ifenthaler and Schumacher, 2016).

Moreover, privacy is an important aspect when it comes to LA. Students recommend clear transparency and trustfulness of LA applications (Ifenthaler and Tracey, 2016). By providing the users with access to and control over their personal data, confidence can be enhanced (Prinsloo and Slade, 2015). One further aspect is the possibility of making an interpretation of the learners' information very simple. By visualization of the data, learners, lecturers, as well as other stakeholders can easily identify a good or poor performer (Ebner et al., 2015). Furthermore, individual information can be collected from different sources. While login information and the frequency of particular websites are classically representing quantitative data sources, entries in forums or blog, for example, have to be interpreted as qualitative resources (Ifenthaler and Schumacher, 2016).

IV. Material and Methods

Study Design: Because usability is subjective, non-quantitative state, measurement was not exact and required sampling and statistical analysis: Usability evaluation was undertaken with an understanding of the gap between user expectations and attribute performance perceptions to determine a connection between usability of a learning application, it use, and application for mobile learning.
Study Location: This was university and higher institutions of learning based study done in Department of Computing of Kampala International University western campus.
Study Duration: April 2017 to November 2018.
Sample size: 158participants.
Sample size calculation: The calculation of minimum sample size for this research was based on formula that was introduced by Luck, Taylor and Robin (Luck et al., 1987) as follows: Where S= sample size, N= Size of population, p= population proportion or, q=(1-p), e is the proportion of sampling error, and Z is the standard score corresponding to a given confidence level. Assuming a 95% confidence level, 0.5 standard deviation, and a margin of error (confidence interval) of +/- 7%, on total of 200 and staff students who are in the category above, a sample of 158 respondents was subjected to thesubjective study.

$$So = \frac{(Z)(Z)xpq}{(e)(e)}$$

Subjects & selection method: The respondents of the research were chosen through sampling method by using the non-probability sampling. The non-probability sampling is the "convenience sample". Convenience sampling uses respondents that are conveniently found, this saved the researcher time and cost accordingly.

Inclusion criteria:
In this research study, sample population of the result was staff and undergraduate students at Kampala International University. The population was limited to second- and third-year students in the undergraduate program and staff in the college of Science and Information Technology. This population was targeted because the researcher believes that this group was able to perceive product quality of the smartphone devices they possess, enough to offer the best experience and knowhow and were able to satisfactorily give adequate response about the usability aspect of mobile learning applications.

Exclusion criteria:
1. Students who did not own any mobile devices or smart phones

2. Staff who did not smart devices

3. students who were not yet in their second year of course

Usability framework development
From the researcher's review of existing works, it is apparent that most existing models for usability do not consider mobility and its consequences, such as additional cognitive load in addition to safety and privacy, and this complicates the job of the usability practitioner, who must consequently define their task model to explicitly include mobility. One might argue that the lack of reference to a particular context could be a strength of a usability model provided that the usability practitioner has the initiative and knows how to modify the model for a particular context. However, in respect to the above, mobile learning is different where the practitioner's knowledge of the context is limited and the environment is dynamic, and hence the researcher believes that incorporating mobility; which is also evidenced in the level of learnability, operability effectiveness and understandability, in mobile learning application context allows designers to produce good quality software with maximized usability attributes.

The researcher therefore based on the facts above to come up with a more comprehensive criterion tool for usability measurement and hence incorporates several usability factors generated from different existing frameworks which include Learnability, Understandability, Effectiveness, efficiency, Serviceability, Operability and Satisfaction. The researcher believes that the attributes above are able to measure usability and provide complete and satisfying results since all major attributes as proposed by the stated models are incorporated within this model.

The developed usability framework

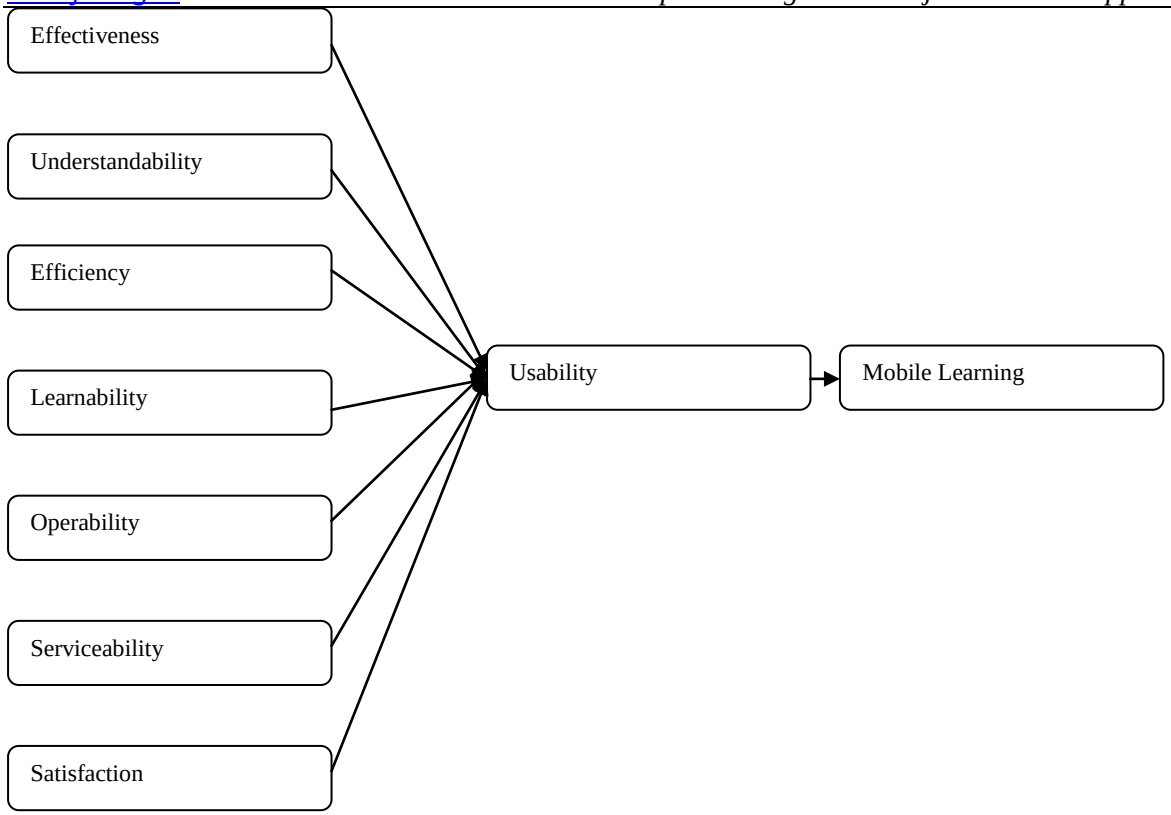

Fig 1: developed framework

Table1: The expanded framework

The developed usability evaluation framework was expanded further to detail the sub-attributes of the usability attributes included in the framework. The different attributes were broken down into corresponding sub-factors according to ISO-9241. The different sub-attributes created a better platform for developing metrics against the user goals from the subjective test instrument.

Interactivity Navigation /Orientation Multimedia usage Feedback		**Effectiveness**		
Input/output ability		**Understandability**		
Time required Effort required		**Efficiency**		
Help/ Support Cognitive load Learning potential		**Learnability**		

Customizability/ Personalization Error tolerance User control Readability		**Operability**	**Usability**	**Mobile Learning**
Technical support Upgrades Guarantee		**Serviceability**		
Resource Usage Engagement Screen layout Screen Design Safety/privacy	Performance Attractiveness Security	**Satisfaction**		

Data collection Instrument Design

Subjective test instrument design: The data collection instrument for this study was based on the Goal Question Metric model. It was based on the usability measurement model for mobile learning and user interface design. The Goal Question Metric (GQM) approach which was originally developed by Basil et al 2012, is what the researcher referred to in developing the metrics for usability evaluation of the mobile educational apps. Basically, GQM was employed to define and evaluate goals for a particular project or environment, it can also be used to larger perspectives and can be adaptable to different environments and software development organizations, as confirmed by international companies such as (NASA, Siemens, and Philips). Presently it's a de facto standard for defining measurement models (Basil et al, 2012)

The subjective metrics from the definition of the GQM model discussed in the previous chapter were used to develop the evaluation instruments, that is, objective test task list and the usability testing questionnaire. To develop the instruments from the usability aggregation into the developed model, different goals were developed under each usability sub-factor, and hence the researcher came up with the following attribute goals in the appendix I (subjective test questionnaire). The metrics were developed against the goals in the table below, which derived from the goals reflected by the usability attributes.

Prototype development and data gathering overview
To understand the usability of mobile learning mobile applications, the researcher developed an application prototype. The prototype was then a basis for evaluation of usability. This helped to gain insight about how a mobile application can be used by students and instructors. A data collection instrument (questionnaire) based on the proposed framework and GQM and used to evaluate the developed prototype.

The researcher aimed to design and develop a prototype which is a module of a mobile learning application. There are a number of platforms that run on smartphones including Android, IOs, Microsoft and Blackberry OS, and there are a number of tools that can be used in developing mobile applications however, the user developed an application that runs on android devices and hence Android IDE (Integrated Development Environment) platform was employed by the researcher. This was because most applications for android are open source and the platform is more user friendly and consequently, android platform exists on more mobile devices as compared to other platforms. Therefore, the prototype was developed using Android Studio 3.1 which provided tools for fast application development for different Android devices. The application was then used in the evaluation of usability of mobile learning applications and feedback was presented by the participants in the questionnaires.

Prototype development requirements: the research employed a number of tools, both hardware and software tools to design and develop the application prototype. A laptop computer with the following hardware requirements required to develop the application prototype were; at least 4GB RAM, 500GB of Hard disk, 5.3GHZ CPU, And software requirements of at least Windows 8.1, with Android SDK (Software Development Kit), (Java development Kit) jdk-8u17, and (Java Runtime Environment) jre-8u5.

Data collection
The GQM model from which the researcher adapted the structure of the data collection instruments offered a comprehensive structure for evaluating usability. It describes usability attributes and how they are linked to User

Interface Design criteria and metrics for accessing each criterion and the evaluation instrument for obtaining data for each metric.

There after the use of the application by the respondents, it was requested of each respondent to rate the usability of the application using the tools above. Bearing in mind the major aim of the study to evaluate usability level, user interfaces and design rather than functionality, was majorly focused on while paying less attention to other software quality attributes of functionality. Hence these instruments were used to obtain data for evaluating usability of the prototype application, which was a module of mobile learning application basically designed with an aim to improve interface design and ease user interaction for mobile learners and teachers especially incorporating the mobility factor.

Thus, the data collection process involved implementing the prototype by deploying it with a learner and or teacher, testing it on a real mobile phone that uses android OS while responding to the developed usability data collection tools mentioned above.

Usability testing and Evaluation

A description of the usability consists of appropriate measures of user performance (effectiveness and efficiency), and of user satisfaction. Because the relative importance of components of usability in this study depended on the context of use and the purposes for which usability is being described, that is mobile learning, since there is no general rule for how measures can be combined, it was necessary to provide at least one measure for each of the sub-characteristics of usability, and it was not necessary to repeat measures in several other different contexts. The measures rate in percentages and correspond to standard usability measures.

Therefore, the researcher in study considered subjective measures to do a comparative analysis to find out if both naive, regular and expert users can all experience a good level of usability. This is deemed a more efficient way to evaluate usability as compared to using two models or products since both may lie below a require usability level for a user group or for a particular context of use, and comparing them could result in a wrong conception on the level of usability. The researcher insists that the usability of one app or model should not be used to evaluate that of another, of course unless one of the products has been fully rated by the IEEE/ISO or any other Standardization entity.

The designed mobile learning platform prototype interfaces are shown below.

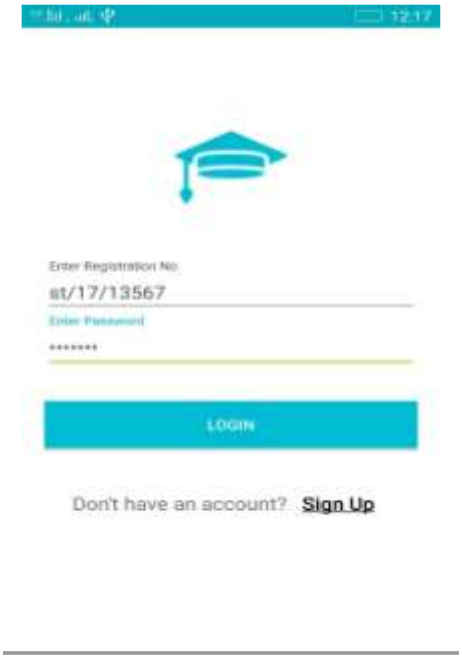

Fig 2: Login form

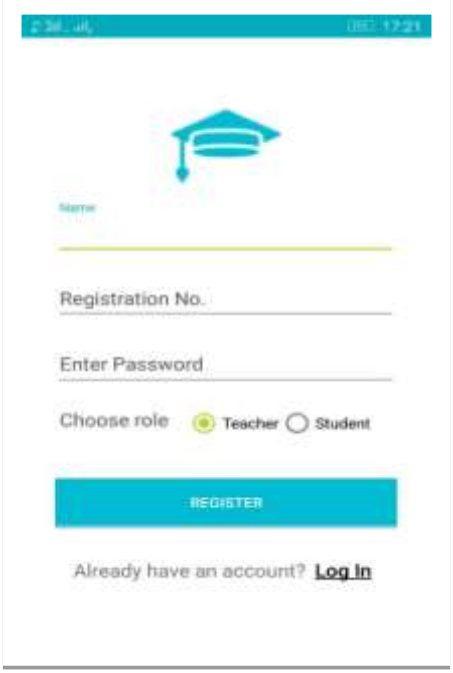

Fig 3: Registration form

Fig 4: Course search

Fig 5: Course Overview

The figures above show some user interfaces of the prototype designed and hosted on the web and deployed for testing by the respondents of the study and described in the methodology. They show sign in and accounts creation pages and course searching interfaces. The interfaces below show the user dashboards for both student and staff.

Fig 6: Teacher Mode

Fig 7: Student Mode

Prototype Implementation and Testing

In this phase, the prototype developed which is strictly a teaching and learning environment was implemented and tested. This was majorly done to test the prototype's level of usability. This evaluation mechanism involved face to face interaction with the respondent as he or she used the prototype where observations were made, and the use of the developed data collection tools which adhere to the mobile learning application usability measuring criteria and was developed with respect to the framework developed from the usability framework. In this study, the researcher ensured that the context of measurement matches context of use, that is, mobile learning by making sure that the conditions for the usability test were actually representative of the important aspects of the overall context of use that is mobile learning.

In this study, mobile learning was considered while prioritizing mobility with its additional cognitive load. The learners' easiness in the performance of the tasks to achieve one's goals while using the mobile learning application and on the move was considered.

Procedure methodology

The subjective test

When the satisfaction questionnaire is used, participants are asked to rate the 64 items related to the interface design of educational apps with a 5-point Likert scale that range from 1 for Not at all true,2 for Not very true,3 for Somewhat True, 4 for True to 5 For Very True. This complete model offers a comprehensive structure for evaluating usability. It describes usability characteristics and how these are linked to UI design criteria. The metrics for accessing each criterion and the evaluation instrument for obtaining data for each metric. Hence this was useful for obtaining quantitative for the usability evaluation.

V. Results presentation

The researcher presents the data findings from the prototype test done under scrutiny and intense observation of user performance to measure effectiveness, efficiency and user satisfaction of the prototype application in the objective test and the survey findings acquired from implementing the structured questionnaire for the subjective test over the sample population. The questionnaire design ensured that the research findings thereof were converted from the subjective qualitative nature to quantitative data through coding using a five-point Likert scale and then analyzed

using statistical package for social scientists (SPSS). The data is hereby presented in tables and, or charts as deemed more appropriate by the researcher. The presented data corresponds with the usability factors presented in the developed theoretical framework.

Sub-factor and Usability attribute performance measurement of the means

The results from the analysis as shown in table 2, below, show that usability factors performed well from the prototype evaluation where effectiveness scored 78.8%, understandability score 89.3%, Efficiency score 92.6%, Learnability scored 86.5%, Operability score 84.2%, serviceability score 67.6% and satisfaction scored 86.2%. On overall average, the final usability score was 83.6% and this is a good score for a mobile learning tool considering mobility.

Table 2: Sub-factor and Usability attribute performance measurement of the means

Sub-factor	**Means**	**S.E. Mean**	**Usability Factor**		
Interactivity Navigation Orientation Multimedia usage Feedback	4.16 4.63 4.65 2.70 3.59	0.05 0.05 0.04 0.05 0.04	Effectiveness (3.94==78.8%)	**Usability(4.32== 83.6%)**	**Mobile Learning**
Input output ability	4.50 4.43	0.04 0.04	Understandability (4.465==89.3%)		
Time required Effort required	4.56 4.70	0.04 0.04	Efficiency (4.63==92.6%)		
Help/ Support Cognitive load Learning potential Control Visualization	4.43 4.20 4.76 4.32 3.92	0.07 0.05 0.04 0.06 0.07	Learnability (4.326==86.52%)		
Customization Personalization Error tolerance User control Readability	4.71 3.13 4.25 4.32 4.64	0.04 0.07 0.07 0.06 0.04	Operability (4.21==84.2%)		
Technical support Upgrades Guarantee	4.01 3.74 2.39	0.07 0.07 0.10	Serviceability (3.38==67.6%)		
Resource usage (4.38) Engagement (4.42) Screen layout (4.38) Screen Design (4.43) Safety(4.35)/privacy (3.93)	Performance (4.38) Attractiveness (4.41) Security (4.14)	0.04 0.06 0.07 0.05 0.05	Satisfaction (4.31==86.2%)		

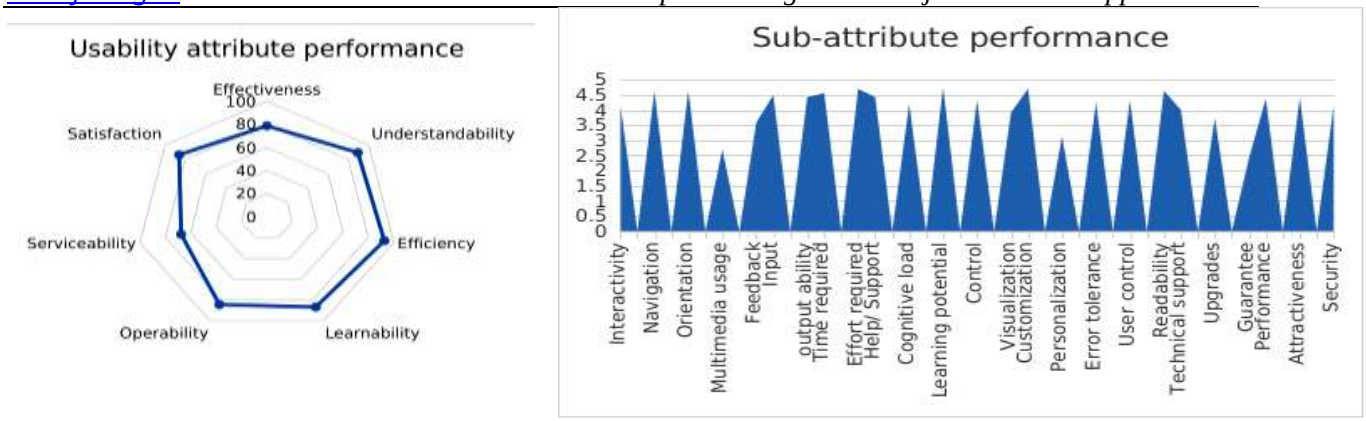

Fig 10: Usability attribute performance

We further visualized the results presented above in the charts in fig 10, and fig 11 as seen above and we realized that input methods and tools available contribute much towards usability. Customization features and effort required to perform tasks took the highest contribution followed by Navigation capabilities, Readability, and Orientation. On the other hand, Application Guarantee contributed the least towards usability.

We further studied the relationship of the usability factors to total user satisfaction as shown in the figures below;

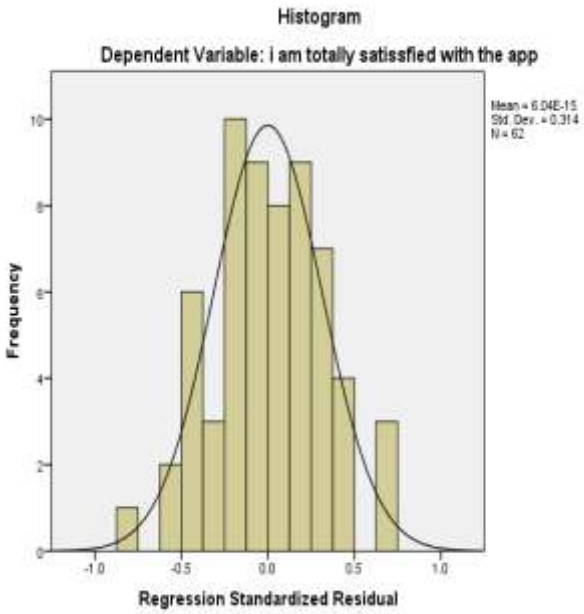

Fig 8: Regression of results towards total satisfaction

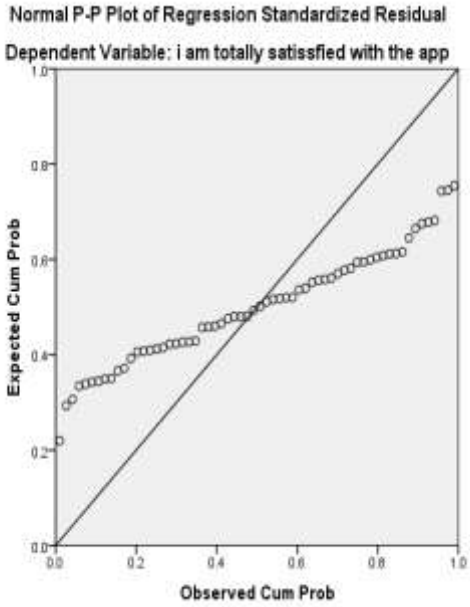

Fig 9: Normal P-Plot

The results above show an average level of satisfaction with the app as the figure above shows a normal distribution and the frequency of user rating tends to the center at 0.0 for the standardized residual from the regression analysis. The different usability factors independently affect the user level of satisfaction with the prototype application under study both negatively and positively. From the histogram, we can see that height is relatively symmetrically distributed about the mean, though there is a slightly longer left tail and the reference lines indicate that sample mean is slightly lower than the hypothesized mean, but not by a huge amount hence the results significantly showed that user total satisfaction depends on the sub-factors.

VI. Discussion of results

The discussion of results was done in this section to critically understand the importance and effect of the analyzed data and make inferences about the study objectives and validate the conceptual framework. The researcher therefore looked deeper into internal usability metrics according to ISO 9126 that are used for predicting the extent to which the mobile learning application prototyped in this study can be understood, learned, and operated, attractive and compliant with usability regulations and guidelines.

The results presented above were gotten from the subjective study that aimed to test for the user levels of satisfaction and how these levels could impact the overall use of the application under study. The usability of the application was hence measured and individual scores of attributes of usability were analyzed. The relationship between the independent and dependent variable were measured using correlation to measure significance of an existing relationship and its effect discussed where the usability factors were correlated with the overall user satisfaction in using the application for mobile learning. The data was validated by the measure of variance to determine outliers and distribution of data around the means of individual attributes. Also, the subjective dataset analysis results included missing values for some variables.

However, the missing value effect was not big enough to prompt the researcher to replace the missing values which would best be done using mean imputation as provided by IBM SPSS Statistics because this would affect the variable. The results presented in the previous section reported the mean value and the standard error of the mean and hence can be used to make valid inferences about the usability of the application under study.

Therefore, the different metrics from the developed usability measurement framework in this study are further analyzed and discussed considering the weight of each sub-attribute contributing the overall usability score calculated from individual mean scores converted into percentages. The ratings differ from low, average and high for Weight (W) of 60%>=W<70%, 70%>=W<80% and W>= 80% respectively indicating a low, average and high level of usability respectively.

Learnability

The metrics scores for each learnability attribute were analyzed and the user rating from experience about how quickly they could learn the prototype function and how easily they could find help items, showed a high rating for the learnability of the prototype under study. According to ISO/IEC 9126, learnability metrics should assess how long users take to learn how to use particular functions, and the effectiveness of help system functionalities and documentation.

From the analysis in the previous section, a learnability score of 86.5% was achieved with an average error of 0.05 showing high tolerance. This weight indicated a high level of learnability. The different sub attributes that were assessed included the Help/ Support functionalities of the application under study, the effect of cognitive load as a result of user mobility, the learning potential provided for in the app, user control provision capabilities and the extent to which the design is appropriate in terms of visualization. The mean scores from each of these contributed to the total weight of the learnability attribute. Since the metrics for the attribute were validated, the score can hence be used to infer that the prototype design can be used to develop the complete mobile learning application that offers a high level of learnability.

Understandability

The understandability of software applications was measured using metrics that assessed whether new users can understand two things; whether the software is suitable and how easily the app can be used for particular tasks. In this study, the different sub attributes that were measured to assess understandability included input and output features provided by the interface to the user and how easily the user could access and use these features and become productive towards goal achievement while being mobile. The proportionality of the functions and how easily they were accessed, understood and used was assessed (ISO/IEC 9126). From the analysis of the user ratings, the understandability score of 89.3% was achieved with a Standard Error mean of 0.04 indicating high tolerance for all kinds of users from novice users to expert users. The score shows a high rating in terms of usability where users found that the UI of the app exhibits very good input and output features and hence found it easy to understand the

app and use it effectively. This shows that even for new and inexperienced users, the app's user interface allows them to understand and use the app with ease.

Effectiveness
The effectiveness of software products has more to do with mapping the system and user requirements of the software to implementation and the accuracy and ease of implementing a given task or user goal. The proportion of functions the user was able to perform successfully was assessed considering the appropriateness of time required and rate of error tolerance. Accuracy and time for the specified goals achieved by users was assessed as required by the ISO 9241-11. The Effectiveness sub attributes considered included; the Interactivity of the UI, Navigation around the UI, the screen Orientation, Multimedia usage and the feedback

mechanisms exhibited by the app's UI. From the previous section, the user rating of the app in terms of the effectiveness of the app was 78.8% for the attribute weight with a S.E Mean of 0.045 indicating high error tolerance. The results show an average rate of task completion in the given context of mobile learning and with accuracy and speed and hence appropriate for the given context of use. The correlation of the objective and subjective measures of effectiveness showed a significant positive relationship between the measure and therefore researcher therefore has enough evidence to state that the usability measure used to assess the effectiveness of the mobile learning prototype and hence mobile learning applications.

However, improvement in regard to the feedback mechanism from the app's functionality that provide progress messages or hints to the user as one is using the app, as well as error messages that are brief to the point and help the user to bounce back from a blunder. The results from the feedback mechanism in terms of error reports showed an average rating and hence improvement is required. According to wolfe, 2004 a poor feedback mechanism and error recovery features present hardships to the user and reduces usability levels (McCracken and Wolfe, 2004)

Efficiency
According to ISO/IEC 9126-11, the efficiency metrics are used for predicting the efficiency of behavior of the software product during testing or operating and in this study both the objective and subjective tests provided for the requirement. To measure efficiency, the researcher considered the appropriateness of the time required to complete a given task or a group of related tasks, the appropriateness of resources required to complete a task in terms of the I/O utilization, and the appropriateness of memory size required. The researcher also assessed the appropriate of the user effort required to complete a given task. From the analysis in the previous section, the user rating of the efficiency of the prototype application was 92.6% with an average S.E mean of 0.04 indicating a high error tolerance. The overall score indicated that the user found the app highly usable in terms of user effort required to complete a given task and the time taken for task completion.

Serviceability
The serviceability of software refers the support and help a user gets from providers to ensure good maintenance to facilitate user transactions with the software product and hence improve productivity (Hussain, 2012). To achieve user goals, a continued provider service mechanism in terms of technical support, maintenance logs uploads and feedback, user guarantees and updates or upgrades availability. In this study, the serviceability metrics used included; technical support, Upgrades and user Guarantee. The results from this study indicated an average rating for the overall metrics. This shows inappropriate or insufficient serviceability of the application under study. It should however be noted that the prototype under study was evaluated subjectively without the provider support, in this case, the researcher and there were no other versions of the prototype application to cater for updates and upgrades. The researcher recommends the involvement of the provider support in the implementation of the final application to be developed for mobile learning.

Operability
The operability of software can refer to the extent to which a user can operate and control the software and the operability metrics according to ISO 9241-10 can be categorized into; the suitability of the software for a task, the self-descriptiveness of the software, the controllability of the software, the conformity of the software with user expectation, error tolerance of the software, and suitability of the software for individualization. Therefore, the

individual operability metrics assessed in this study included; personalization and customization features, error tolerance, user control provision features and the readability of the UI. (R Tahir, 2014)

The results from the study showed a high rating of 84.2% with and standard mean error of 0.056 showing high tolerance rates. However, there were low ratings for customization features. User control provided by the application was rated high with a mean of 4.32 and a standard mean error of 0.06 showing high tolerance. The overall rating for operability was and hence the research can infer that the prototype design can be used to develop a final mobile learning application and use the same unit of measurements used in this study to assess its use.

Satisfaction:
The user satisfaction of the application was measured subjectively using measures provided from the SUMI and was customized to fit a mobile context in terms of teaching and learning. The internal metrics to assess attractiveness and the appearance of the software, and was influenced by factors such as screen design, layout and color. In addition, to fit the context of use, resource usage in terms of memory, processing as well as battery consumption were considered. (Sabina Barakovic, 2017)

Moreover, the mobility of the users presented safety challenges. Therefore, the overall performance of the app, the attractiveness of the UI and the security provided for in terms of safety and privacy were assessed and considered to contribute to the overall user satisfaction. The study result showed a high rating for the user satisfaction with a standard mean error of 0.054 indication a high tolerance. A correlation of results against overall satisfaction showed that there is a significant relationship between the different usability factors assessed in this study and user satisfaction. The correlation coefficients from individual sub factors as showed in Table 5.2.0.6.4 were used to make a judgment as to whether a sub-factor is significantly related to overall user satisfaction. And the results would be used to predict quality characteristics without measuring them directly since satisfaction is measured subjectively. This was done because the overall satisfaction from use of a software product would be used to determine whether the users would use the final product or not. The results hence indicate the users will be satisfied using a final mobile learning application.

VII. Conclusion and future works

The concept of usability measurement ensures that the interactive designer understands the metrics that provide the basic users with surpassing levels of usability through enabling the users themselves with the ability and tools to measure the quality of the intermediate deliverables as provided by the mobile learning prototype in this study, and thereby predict the quality of the final product to be implemented by the institution under study. The study allowed the prospective users to provide a measurement and correction mechanism to the designer to identify quality issues and in turn initiate corrective action as early as possible in the development life cycle to avoid among other avoidable costs, operation and implementation issues.

The usability metrics which effectively measure whether a product meets the needs of specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction in a specified context of use, and in this case, mobile learning. The study aimed majorly at providing a basis for usability measurement of software applications more so, mobile applications. The developed framework that was used to evaluate the usability of the prototype application was a customized framework combining different standard frameworks and at the same time the prototype was developed with respect to interactive design objectives. The results from the study therefore should be used as a basis to prove or disprove the relevancy, reliability, comprehensiveness and validity of the framework. This will provide for whether the developed framework can be used in future designs and measurement as an evaluation criterion or not.

The research hints on some of the endeavors required for future work in the same sense where usability and user interaction design is shifting to UX design which should also adhere to hands-on learning experience that will challenge you to get out of your chair and out into the real world to talk to people and test your ideas. More comprehensive model can be developed and generalized to be employed in different methods for usability evaluation in the cases of expert evaluation, inquiry and usability testing. More sophisticated and costly mechanisms

of model validation can be employed in future research since the researcher in this study could not employ such methodologies of model validation.

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APPENDIX I: Subjective test Questionnaire

A modified plan in reference to the International Journal of E-Learning and Educational Technologies in the Digital Media (IJEETDM) and the Society of Digital Information and Wireless Communication (SDIWC), 2014 (ISSN: 2410-0439)	**Metrics**	
I find it easy to interact with the application	Number of mistakes during interaction	
The app provides interaction like collaboration or sharing features	Number of collaboration /sharing options	
The app provides easy to use touch screen input or virtual keypad.	/give input Rating scale for understand output	
It is easy for the user to navigate across the user interface	Number of mistakes during navigation	
The app provides clear and understandable navigation keys	Rating scale for navigation	
The app UI indicate easy scrolling if a lot of information is present	Rating scale for screen scrolling options	
The app UI provide easy main menu for navigation	Success/Failure rate to use main menu	
The app provides a visual display to show the loading process.	Rating scale for visual display	
It provides multimedia usage of UI appropriate for the user	Rating for multimedia usage	
The application provides useful voice instructions.	Rating scale for voice instruction	
I can use it without any instructions.	Rating scale for instructions	
Both occasional and regular users can easily use it	Rating of scale for naïve user	
The UI provide appropriate feedback	Success rate for understanding pedagogic feedback Rating scale for pedagogic feedback	
I am comfortable with the screen orientation of application.	Rating scale for screen orientation	
The app provides clear and understandable navigation keys such as back/next buttons to move to previous/ next screen	Rating scale for navigation keys/buttons	
Interface provide easy ways of input for the user	Number of mistakes to enter Rating scale for input	
UI provide easy to understand keypad	Rating scale for keypad design	
Is it easy to understand the output for the user	Rating scale for output	
The application provides useful tutorials that explain how to perform a task/activity	Rating scale for tutorials	
It is easy to understand the language used in the application.	Rating scale for language used	
I don't need to remember a lot of information throughout several actions to perform a task.	Rating scale for recall	
The UI provides useful task related clues/ hints through several actions	Rating scale for clues and hints	
Users are capable of recognizing the functions and their actions	Rating scale for function recognition	
Users can easily recognize an icon/link/button	Rating scale for link/button recognition	
The UI provide appropriate content/information for Users	Rating scale for content	
The app is easy to learn for the user	Rating scale for learnability	
Appropriate learner control is provided for in the app	Rating scale for learner control	
The app UI allows for personalization	Rating scale for personalization	
The app UI allows for customization	Rating scale for customization	
The application gives error messages that clearly tell me how to fix problems.	Rating scale for error messages	
Interface provide short errors messages	Number of errors per task	
The application provides appropriate controls	Rating scale for user controls	
I can recover from mistakes easily and quickly	Rating scale for recovery rates	

The application provides easy readability	Rating scale for readability	
The text size appropriate for users	Rating scale for text sixe	
A small amount of time is taken by the application to load	Rating scale for loading application	
Less effort is required for task completion	Rating scale for effort required	
The apps allow multitasking without hanging.	Rating scale for multitasking	
The time taken by the UI to respond appropriate	Rating scale for response time	
The time is taken to complete a given task is appropriate	Rating scale for completion rate	
The app allows for sharing with connected and synchronized devices.	Number of collaboration /sharing options	
The app does not require upgrades regularly.	Rating scale for updates	
The app does not require separate adds in to work well.	Rating scale for adds in	
There are previous versions of the app still functional.	Rating scale for app versions	
The app installs on newer version of the operating system.	Rating scale for os versions	
The app installs on older versions of OS.	Rating scale for os versions	
The app caters for publishing in various file versions and types.	Rating scale for publishing	
It allows for check in, check out and recovering unsaved changes.	Rating scale for recovery rate	
The app guarantees the user against any harm while using it	Rating scale for app safety	
The app collects data and error logs and uploads it to providers.	Rating scale for app error logging	
I can access the learning resources at times and places convenient to me.	Rating scale for resource access easiness	
I can use time saved in travelling and on campus class attendance for study and other commitments.	Rating scale for time saving	
I am allowed to work at my own pace to achieve learning objectives.	Rating for personal pace allowance	
I decide how much I want to learn in a given period.	Rating scale for app versions	
The screen design is attractive and enticing.	Rating scale for app attractiveness	
It helps me be more productive.	Rating scale for user productivity	
It gives me more control over the activities in the course and my life.	Rating scale for user control	
The screen layout clear and consistent	Rating scale for screen layout	
The Interface is engaging for the user	Rating scale for user engagement	
The app provides insurance to the user against any harm while using it	Rating scale for user insurance	
I feel safe while using the application	Rating scale for safety	
The app does not consume system resources to perform	Rating scale for resource consumption	
I would recommend it to a friend.	Rating scale for app recommendation	
The user is satisfied with over all functionality and performance of prototype application	Rating scale for user satisfaction	