Learnability Evaluation Model for Android Mobile Applications

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ABSTRACT
Educational mobile applications have become an important tool in education. In addition, its spread played a major role in this field. In order to use it efficiently, we must adopt the concept of learnability. By applying some standards, learnability characterizes how easy it is to use a certain application. In other words, it is the answer to whether the users can complete simple tasks on their first attempt. This paper proposes a comprehensive evaluation model for learnability that can help define clear learnability dimensions based on several approaches to measure learnability. Hence, improves users' learnability while using a mobile application targeting Android system mobile applications. The research approach will follow these steps: integration of multiple resources, building a framework, testing, and reporting results. We proposed a new learnability evaluation model for Android mobile applications. We will use this model as a basis for our framework to measure how learnable any Android mobile application is. Moreover, generates results using three integrated learnability methods: Performance measurement learnability curve as a logarithmic approximation, Petri-net approach through fitness value, and analytics through logs as well as other related measurements. The results of this study offer clear statistics for measuring Learnability and assets to improve the approach to designing a mobile application to be more learnable for users.

Keywords
Learnability evaluation model; Android application; Mobile users; Learnability Mobile applications; learnability; easiness of learning

1. INTRODUCTION
In a sharply rising technology world, developing an easy-to-use application is becoming more diverse and more complex due to the new features and functionalities added, which are being acquired by the rapid change of technology and the wide range of user segments. In human-computer interaction (HCI), the role of an excellent user interface (UX) is a huge aspect of any application [1, 2]. Nowadays, a good user interface is a matter of survival for systems where users can freely and rapidly move between many alternatives, whether websites or mobile applications, as users would abandon the system if it is too difficult and opaque to use.

One of the most important attributes of usability is learnability [2, 3, 4], which generally can be described by how easy it is to learn the system. Nonetheless, some researchers refer to learnability as the most fundamental attribute [4]. Also, highly recommended to involve a clear evaluation of learnability when evaluating usability [5]. A mobile application's learnability is considered even more significant today than ever. Furthermore, users will have to invest their time and effort to install applications and start using them. However, if the application appears to be difficult to use, they can quickly uninstall it and look for another one. Hence, a new approach is needed to solve the issues of usability attributes, including Learnability [6]. By applying some standards, learnability characterizes how easy it is to use a certain application. In other words, it is the answer to whether or not the users can complete simple tasks on their first attempt in a particular software application [7].

While researchers understand the value of Learnability, there is a need for a well-defined, consensus concept and evaluation of learnability for various users [8]. Therefore, we aim to propose a comprehensive evaluation model to measure Learnability for Android applications. It can help application owners evaluate their applications using clear metrics and measurements, improving users' experience using a specific mobile application. Moreover, we aim to test the proposed system on four applications, two targeting children, one in Arabic and the other in English. On the other hand, the other two are for adults in which also one is in the Arabic language, and the other one in English. The goal is to verify the proposed system's learnability and other related measurements and report results. We consider developing a clear Learnability evaluation model with a clear, detailed dimension system that can measure Learnability for any Android application as our major contribution since it did not exist previously up to this detail.

2. RELATED WORKS
There is a lack of studies in measuring learnability for mobile application users, and Learnability, in general, is limited in several research types. An extensive search was conducted about attractiveness and learnability factors by NorzilaNgadiman et al. [10] it was found that only 10% of the found papers were related to 'learnability.'

Learnability standards include views of users, such as limited action at each transaction in a mobile application, allowing continuity and self-description as well as fast finishing of a certain targeted task. On the other hand, it is a key problem for designing mobile applications due to users' different preferences and needs [11]. As stated by Herrera et al. [12], If the specifics of the learnability requirements are not correctly implemented, it can negatively impact the mobile application users.

In terms of methods suggested to measure learnability, a procedure proposed by J. Brown [13], called task-action grammar (TAG), is an iterative prototype that provides valuable feedback for improving mobile application design. The method tests the interface's learnability and other usability attributes by communicating with the user interface and observing user interaction. TAG uses an action-based guidance system, which keeps track of the user's route and navigation paths.

Nevertheless, most related work in terms of learnability discusses various techniques and approaches proposed by researchers to help developers adapt and enhance learnability in their mobile applications. Five approaches were found: User-based, Design-based development, knowledge-based services, interaction model, and a Framework-based approach.

The user-based technique proposed by M. Papagelis and D. Plexousakis [14] is a famous interface design technique, where the applications are evaluated based on their interfaces, deciding whether to accept or reject the whole application. The evaluation is conducted to observe how developers designed the interface based on the user's behavior on each application's interface. By adopting this approach, it is advised by A. N. Touch et al. [15] that developers shall focus on designing easy-to-learn interfaces in consideration of performance rather than only considering how the interface looks. For example, having many images in one interface can mislead the user and use unnecessary resources.

Design-based development, suggested in [16], provides guidelines in application development, for instance, presenting all the information related to each other in one for conducting interface. The main goal is to study the interaction of users with the system and then give the developers a chance to reverse the design phase based on the users' behavior. Choosing the design pattern is an important step to help developers reach maximum learnability with minimum time and effort. Hence, the knowledge will be increased in each design phase based on the received feedback [17].

Knowledge-based services mentioned in [18] include users or specialists in creating applications, particularly in the elicitation stage of the specifications, which must consider the learnability factor. Developers and experts will join and contribute their ideas for improving user preferences and context and adjusting user queries. Finally, experts can make the final decision: either to start a reengineering phase for the design or keep it as it is. Nevertheless, these discussions are fertile ground for conflict of interest among the two parties [19].

An interaction model mentioned in [20] can help build a dynamic application where it gives the ability to create services to provide users with specific tasks and personalize and customize the application's behavior. This model is typically used to maximize the usability factors such as learnability [21]. Software agents can also manage complex interaction models to improve applications' conduction. However, interaction is not mandatory for all application forms.

Using a framework-based approach, as suggested in both [22] and [23], will assist developers in focusing on object-oriented technology, which will result in reducing their time. A framework is a semi-complete application in terms of structure; its benefit revolves around the ability to customize or extend to create a full application. A structure will allow developers to integrate more complicated features into their applications. However, some other applications have minimal operability problems with application platforms.

Moreover, Bernd et al. [24] stated that there is an insufficient explanation in the related work for the theoretical approaches suggested by researchers to improve the learnability factor; hence many developers don't follow any of the suggested approaches rather, they start designing and implementing their application immediately causing issues in learnability for a huge segment of users. Alistair [25] concluded that designers until today don't have proper guidance for building user interfaces in terms of ease of use and reduction of time during the learning process. In addition, cultural differences in each community must be considered to accommodate the requirements of different users [26].

Researchers have demonstrated that transmitting complex new information to visually impaired users in an easy-to-learn, simple way is extremely hard. Yet, one of the most commonly useful ways is using vibrotactile stimuli [27]. This technology has proven two main things: to improve communication by using the sense of touch to compensate for deficiencies in other senses [28]. Second, using vibrotactile stimuli improves the user's experience by engaging in additional communication channels along with standard ones such as audio and visual channels [29]. One of the key elements in the design and implementation of haptic icons is learnability.

Consequently, understanding the process of learning the significance of a series of haptic icons in haptic icon research has been a significant issue [30]. In some cases, icons are not meaningful, and users must learn the link between the stimulus and the meaning. For instance, when tweeting, the sound of submitting a tweet indicates the reception of a message by the Twitter application; another example is Windows error sounds. It is not easily learned the first time, but when hearing them more frequently, the sound links it to its meaning once heard [31].

Enriquez et al. [32] proposed a three-stage approximation to learn the association between haptic icons and their meaning. The first stage is a self-learning process, in which users learn the association by their exploration with a little help, where the haptic stimuli are presented along with the meaning. The meaning representation is typically audio rather than text-based since we deal with visually impaired users. The second stage is based on enforcement, and the user must recognize the associated meaning of the haptic stimulus and receive feedback on whether their answer was correct. The final stage is the same as the second but without any feedback.

A study in Learnability of smartphone haptic interfaces for visually impaired users [33] designed a mobile application to assist users in learning the association between vibrotactile stimuli and the notifications of commonly used mobile applications. The proposed application used the gamification stage to improve the learnability process of the visually impaired. The study resulted in the improvement of the visually impaired users in terms of recognition rate and their subjectivity of perception of haptic icon recognition. The study also stated that using the reinforcement learning stage was sufficient for visually impaired users to complete the learning stage.

In terms of based technologies, diverse initiatives and strategies for mobile phone applications were introduced to assist visually impaired users [34]. BrailleType was introduced in [35], developed using the single-finger text entry method based on the Braille alphabet. The performance was evaluated against Apple's VoiceOver approach with a group of visually impaired participants. The result of this evaluation was considered to be easier as well as less error-prone. Another tool is 'Perkinput' [36], a touchscreen-based text entry method for visually impaired users; it was also evaluated against iPhone's accessible text entry method, VoiceOver; it is found that Perkinput was faster and with half errors compared to iPhone's VoiceOver.

VB Ghost [37] is an educational gaming application; it is primarily built for visually impaired users who are known as advanced learners and are already familiar with many terms in English. Haptic and audio feedback allows the player to provide input into a braille game, but there is no implementation or assessment report. Likewise, defining and explaining the best technical solution without an implementation or assessment study is difficult. New technology was introduced by Lutfun Nahar and Azizah Jaafar et al. [38] called 'mBRAILLE'; it is an effective technological solution that can help visually impaired students of Bangladesh to overcome the challenges in learning Braille. This proposed technology aimed to design usable interfaces and how well they will enable visually impaired students to learn simple Braille. The application aims to learn Braille in both Bangla and English on mobile phones. The respondents of this application reported being pleased. The students and blind schools' teachers suggested introducing mBRAILLE as a course so that beginners would practice and learn to remember the Braille dots on their own.

3. MODEL OF LEARNABILITY

In various standards and evaluation models, learnability is stated as one of the critical components of usability. In IEEE Std. 1061, ease of learning, and comprehensibility are listed as factors directly impacting usability [39].

In order to build a framework that can measure Learnability, we first need to combine several approaches to gain more benefits. The base method represents a statistical approach based on a definition by Jakob Nielsen [9] as "the effort for the user to reach a reasonable level of proficiency or a steeper incline for the first part of the learning curve." Hence, first of all, we need to define the learnability curve; the learnability curve as a logarithmic approximation trendline can be defined by the equation [40]:

$$\boldsymbol{Y} = \boldsymbol{c} \times \ln(\boldsymbol{x}) + \boldsymbol{b} \quad (4)$$

Where we can say that and are the coordinates, is a constant defining the displacement of a curve, and is a sought-for parameter defining the inclination of the curve. In order to calculate , we can calculate it by using the least squares fitting using the following equation [66]:

$$c = \frac{n\sum_{i=1}^{n} ei \ln(ti) - \sum_{i=1}^{n} ei \sum_{i=1}^{n} \ln(ti)}{n\sum_{i=1}^{n} \ln(ti)^2 - (\sum_{i=1}^{n} \ln(ti))^2} \quad (5)$$

Where is the total number of tests within a session, is the calculated efficiency for a task , and is the time of completion of the task .

Now, to calculate (E.5), we need to define efficiency since it can take more than one definition per the purpose where it will be used [41]. Efficiency could be calculated in different ways. Since our system will measure the Learnability of one task at a time, we can say that it could be a relation of time of completion to the number of tasks performed. Hence, the following equation will be used in our methodology to measure efficiency:

$$e = \sum_{i=1}^{N} \frac{Eni}{ti} \quad (6)$$

After completing the above calculations, we can say that we are now able to measure the overall system's learnability as a mean of all the sessions by following equation 7 [40]:

$$\bar{c} = \frac{1}{N}\sum_{j=1}^{N} cj \quad (7)$$

Where is the number of sessions, is calculated learnability for a session . Therefore, higher indicates higher learnability.

Second, we will follow the Petri-net approach and the learnability curve as a logarithmic approximation trendline. Petri-net is purposive to measure the learnability of interactive systems by measuring the deviation from the expected way of executing certain tasks [30]. This deviation is measured in "fitness values," which indicates how closely the observed method of interacting with the system matches the anticipated method. The hypothesis is that the rate of fitness values recorded over time in repeated system executions demonstrates the system's learnability [42].

Hence, in our proposed methodology and in order to be able to calculate the fitness value, we need to repeat the execution of test three continued times [30]. The outcome will show "the extent to which user log traces can be connected with legitimate execution routes provided by the interaction model." [30].

The user's behavior through the Petri-net approach will be based on a log file and estimated fitness value. The equation can be described as follows:

$$Fitness = \frac{\sigma\, ti_3 - \sigma\, ti_1}{ti_1} \quad (8)$$

Where the is learnability rates, and the is the time of completion of task .

Also, the proposed system's methodology shall provide the "I give up" button in the UI. When pressed, a current task is indicated as failed. Hence, the fitness value and learnability rates are zero [40].

Finally, we can say that the main power point of this system is integration. Where this system is distinguished by being the first that combines three approaches to measure Learnability: Performance measurement learnability curve as a logarithmic approximation [40], Petri-net approach through fitness value [30], and Analytics [28] through logs as well as other related measurements, all in one system.

4. LEARNABILITY MEASUREMENT SYSTEM

Learnability measurement system by overviewing the scenario for all involved parties. In our proposed system, we will have two main interfaces for two main stakeholders:

- For the owner of the application.
- For the participants.

The application owner can be defined as the person interested in measuring the application Learnability rate in which they have the (.apk) file of the application. On the other hand, the participant can be described as the person who is volunteering to test the application in order to be able to generate results.

Following the methodology proposed earlier, the following table will demonstrate the intended scenarios for both parties.

Table 1 Owner And Participants Scenarios

Owner	Participants
A welcome interface will appear to determine which interface we will go through, assuming we will start at the owner's side.	
• The system will ask the owner to enter their personal information.	NA
• The system will allow the owner to upload a (.apk) application file that measures Learnability.	NA
• The system will convert the file to binary format and upload it to the cloud database.	NA
• The system will ask for a clear definition of the targeted scenario the owner wants the participants to apply during the test.	NA
• The system will automatically install the (.apk) file on the Android emulator.	NA
• The system will display the Android emulator.	NA
• The system will ask the owner to perform the entered scenario in order to compare it later with the mean of the participant's performances.	NA
• During the test, the system will keep track of the times of completion and the number of clicks made.	NA
NA	• The system will ask the participant to choose the application they are volunteering.
NA	• The system will display the scenario that mustbe applied in the emulator.
NA	• The system will download the intended (.apk) file from the cloud database.
NA	• The system will install the (.apk) file automatically on the Android emulator.
NA	• The system will display the Android emulator, start button, and give up button.
After participants are finished, we will calculate session efficiency by following equation (**6**) in methodology**.**	
The system will calculate the Learnability after all participants are finished with their tests by following equations (**4), (5)** and **(7)**.	
• The system will show the result of the learnability test at the owner interface.	NA

5. SYSTEM ARCHITECTURE

The organization of the project structure into three primary categories is known as layered architecture: presentation, application, and infrastructure. Each layer contains objectsconnected to the issue it depicts [44]. LMS system is built based on Layered architecture.

Furthermore, the following architecture diagram illustrates the LMS system.

5.1 Data Flow Diagram

The Data Flow Diagram (DFD) is a method for analyzing and designing data in a structured approach. It's a visual

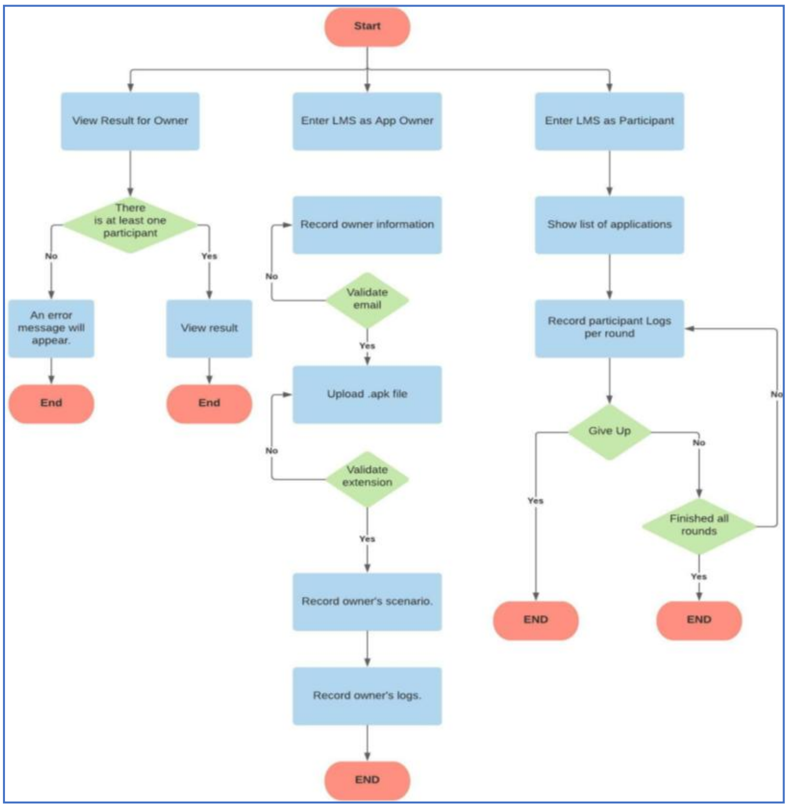

Figure 1 Data Flow Diagram

representation of a system's logic models and data transformations [44].Hence, we can define the DFD from LMS system architecture as follows.

6. RESULTS

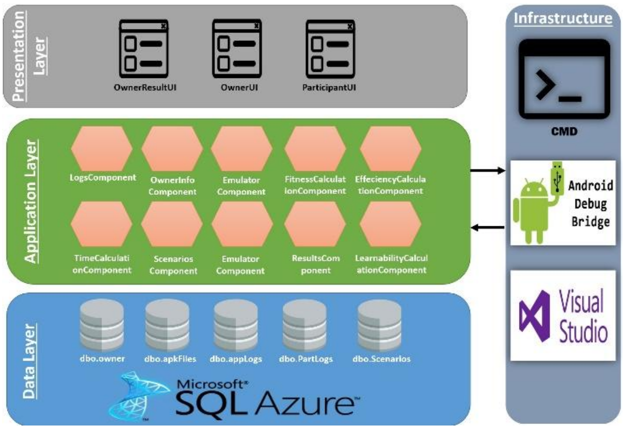

Figure 2 Architecture Design

In this section, we will describe LMS by, first of all, observing its implementation and the system's main functions; also, we will look at the proposed system interfaces and, most importantly, the integration of the system. On the other hand, we will outline the system's testing part along with the testing results.

6.1 Implementation

The LMS system was implemented through "Visual Studio 2019" IDE. We chose LMS to be a windows application; we chose it to be a windows application instead of any other type based on a study that showed the result of comparing conducting the tests in two different ways: Lab test and Remote test [44]. The study was conducted based on four aspects: successful task completion rates, task completion times, subjective ratings, and usability issues identified. The result showed that the lab users spent less time completing tasks than remote testing; in addition, the remote users gave lower ratings regarding their experiment than the lab users [44]. Furthermore, the most difficult component of any usability test is always identifying faults or possible usability problems; lab users tend to find more problems than remote tests related to their concentration level [44].

As a result of the above, LMS is a windows forums application that is intended to use in Usability Laboratory testing. Our system combined 15 sub-forums listed in the following table

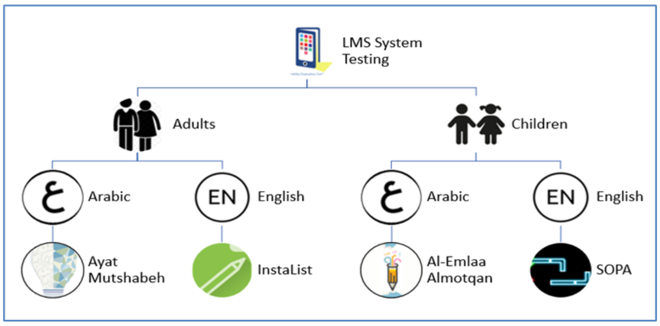

Figure 3 LMS Testing

6.2 Testing

The testing phase was conducted through four applications. The categorization of the applications was as follows:

- Application A: "Ayat Mutashabehah" for adults' similarity in Ayat Al-Quran Al-Kareem.
- Application B: "InstaList" for creating different lists (ex. Shopping list).
- Application C: "Al-emlaa Al-Motqan" application for teaching children Arabic reading.
- Application D: "SOPA" application, gaming app for children.

The diversity of applications was chosen because the LMS system can measure any Android application, Arabic or English, for children or adults. Figure 35 illustrates the diversity.

Table 2. Lms Forum Name and Description

No.	Forum Name	Description
1.	WelcomeUI	This interface will redirect the user to either: Owner, Participants or Owner Results.
2.	OwnerInfo	This interface will require the owner application to enter the following: First and Last name, E-mail address, and application name.
3.	FileUpload	This interface will require the owner of the application to upload a valid (.apk) file.
4.	OwnerProcess	This interface will show the owner the process they are going through for the rest of the experience.
5.	FirstStep	The interface will ask the application owner to input the scenario they want the participants to perform.
6.	OwnerEmul	This interface will ask the application owner to perform the scenario using the Android emulator that will show up automatically with the installed owner's application.
7.	FinishOwn	The interface will inform the owner that all is set up from their side and needs to start performing the testing from the participants' side.
8.	ParticpFirst	This interface will ask the participant to choose the application they are participating in.
9.	PartSec	This interface will start the first testing round by showing the emulator and the chosen application.
10.	PartThird	This interface will start the second testing round by showing the emulator and the chosen application.
11.	PartFour	This interface will start the third testing round by showing the emulator and the chosen application.
12.	Thanks	This interface will thank the participant for their time and efforts with us.
13.	owner login	This interface will ask the user to choose the application in order to show the learnability testing results.
14.	Results	This interface will show the first part of the results, where some graphs are shown based on the testing results.
15.	Statistics	This interface will show the second part of the results, conducted over time, Fitness percentage, Session efficiency (Average), and Learnability scale.

A total number of 40 participants took part in the study, including 13 Males participants and 27 Females participants. All the participant's contribution was voluntary; no economical compensation was offered. The participants were involved in four applications as follows:

- Thirteen participants for Application A (11 Female, 2 Male) with age group: (20-35 years old).
- Nine participants for Application B (7 Female, 2 Male) with age group: (20-35 years old).
-
- Nine participants for Application C (5 Female, 4 Male) with age group: (7-12 years old).
- Nine participants for Application D (4 Female, 5 Male) with age group: (5-10 years old).

The following graph demonstrates the female and male participants per each of the tested application.

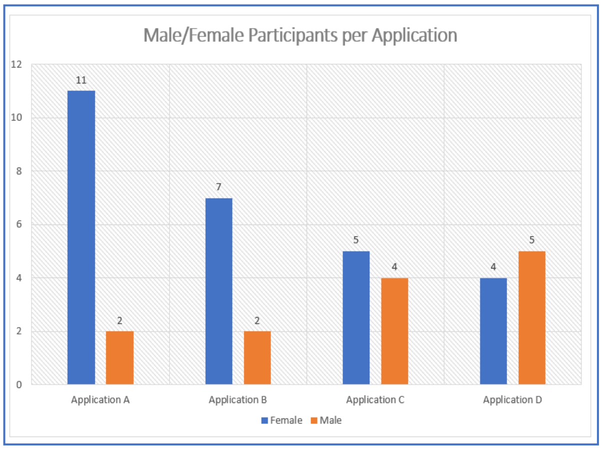

Figure 4. Male/Female Participants per Application

6.3 Discussion

In this section, we will explore the testing phase's results. The results are listed for each of the applications. It is important to say that the call for participation contained a brief explanation of the experimental setup and the study's goals.

For all applications, to test the learnability of the application, we asked the applications owners to provide us with the major function of the application and describe it as a scenario so the participants could perform it.

From the owners' side, they were asked to perform the task in order to be able to record the logs in our database and use it with the Petri-net approach. Conversely, the participants were shown the scenarios and asked to perform them three times. Furthermore, the same task was performed in all three attempts. The "Start" button initiates the test, launches the emulator with the application, and starts the timer for the attempt. Throughout the test, the task scenario was always displayed for the participant. When a task was performed, the participant was asked to click on the "Finish" button to save the attempt logs. Participants were advised to press the "give up" button if they could not complete a task. At the end of the third attempt, the time spent and logs were uploaded to the database under the application ID number.

The following table illustrates the results of the four applications:

Table 3. Testing Results

Application Name	Fitness Percentage	Efficiency Percentage	Learnability
Ayat Mutashabehah	31.49%	8.31%	0.30
InstaList	35.11%	5.99%	0.28
Al-Emlaa Al-Motqan	13.046%	4.39%	0.15
SOPA	41.37%	18.58%	0.34

In this paper, several approaches were integrated to formulate an LMS system. The main target of the system is to assist application owners in having a clear insight of the learnability of their application along with other measurements such as fitness over time and efficiency of the sessions.

Although, Learnability is a concept that measures how easy it is to utilize a certain application based on criteria. It is the response to whether people can do simple tasks on their first try. After conducting several tests using hybrid approach to measure learnability, we believe that many factors may affect the results of such a test. For instance, the sample chosen for testing has a major impact on the results, whether they understand how important it is to perform the task required or just simply click everywhere in terms of trying. This has a major impact on the test outcomes since every click contributes to calculating the session efficiency and hence learnability results.

Moreover, another factor may change the calculations; when we test an educational application, it is important to identify the participants' different levels of understanding and educational

levels. Taking the Arabic application "Al-Emlaa Al-Motqan" as an example, it may differ from one child to another how fast they can reveal the Arabic spelling mistakes depending on their age or even understanding level.

LMS is an effective measurement of learnability and other factors for any Android Mobile Application. However, it might give different ratios for the same application with another sample of participants.

7. CONCLUSION

When creating and deploying a mobile application, learnability is one of the most critical factors. Understanding the process of users' learning curves has been a major challenge in research. Measuring learnability is a crucial part of usability testing. This work proposed a multi approaches statistical model that generates results using three integrated methods: Performance measurement learnability curve as a logarithmic approximation, Petri-net approach through fitness value, and Analytics through logs as well as other related measurements, all in one system, which is capable of producing a learnability measurement of any Android Mobile Application. In terms of testing, it could result in shorter and more efficient tests, more participants, larger datasets, and more reliable data since everything is simply automated in one system. It could be used to test an existing published application or as pre-publish testing under UAT testing. Four different applications were chosen to test and prove the justified adequacy of the LMS system and revealed the learnability results.

In the future, it is recommended to have more security levels when revealing the result of learnability testing for the owner. In addition, we can integrate more learnability measurement approaches to richen the model even more. A survey could be added at the end of the learnability test in order to gain more insights into the participant's observations about the application.

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