

A Learnability Model for Children Mobile Applications

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Abstract: Nowadays, mobile device use among young children is on the rise. A kid using a smartphone or a tablet is a common sight today. This has been triggered by the worldwide advancement of mobile culture & technology. As a result, the number of mobile applications targeting the young children has tremendously increased. Studies, however, reveal that most of the applications are far from perfect. They are less learnable and hardly usable by the young children, as they do not match their mental models. Usability and learnability issues usually have a profound impact on the success of a mobile application. Nevertheless, there has been limited research on these issues for mobile applications designed for children. In regard to this, this paper aims to bridge the gap by reviewing usability guidelines suitable for designing 'near perfect' children mobile applications. We then propose a learnability model to help mobile developers and evaluators in designing and evaluating mobile application for this target population (5-10 year olds). Our discussion concludes that, though there are many mobile applications designed for young children, for any app to stand out and be successful, it needs to be designed with different technological skills, learning capacities and preferences tailored to young children.

Keywords: Learnability Model; Children Mobile Applications; General Interaction; Graphical User Interface; Multimedia and Text.

1. INTRODUCTION

Mobile devices and applications have become an integral part of many children's lives. The market of their mobile applications is now rich and very diverse. The Google play store and the Apple app store, for instance, contains lots of applications targeted for this group of users. There are educational mobile applications, apps for entertainment, communication, and even others developed for children with special needs. The children usually use these devices and applications to play games, learn, communicate, or engage in a plethora of other activities offered.

As a consequence of the rapid advancement of the mobile technology, parents, elementary schools and other learning facilities have started accepting and adopting the devices as educational tools [1],[2], teaching aids [3], and for entertainment [4]. It is believed that educational possibilities for using mobile applications to learn, exist [5], and there is a growing view that they offer a new and exciting era in children's learning phase [6]. Despite this, it should be noted that developing mobile apps suitable for children is different from designing for adults [7],[8]. Children apps require distinct usability approaches, that even include targeting content narrowly for children of different ages [9]. According to [10], "the needs, skills, and expectations of this population segment are drastically different from those of adults".

The interface of the mobile applications should thus be usable and compatible with the cognitive skills of children in order to provide an effective learning experience [11]. Usually, according to [8], "the applications should be funny, intuitive and interesting, so as to keep children's attention for a long period of time".

Though there is a large number of new mobile applications designed for children, [12] cites that many of them are difficult to use, some studies, like by [10] & [11] point out that most of the learnability and usability guidelines used in designing mobile apps have been developed with adults in mind. Many developers, as a result, tend to scale down these guidelines to fit children when designing their applications. This is a critical design issue because children are not just mini-adults. According to [4] "they have their own needs and goals which are not necessarily met by adult tools". When

designing their applications, it is important to aim for the best possible usability for them [13]. The usability and learnability principles are fundamental when designing any software application as they play a crucial role in the success of mobile applications [14]. Not only do they lead to better productivity quickly, but are also a key to the initial adoption or rejection of an application.

Away from the usability design guidelines, We also noted that, most of the existing usability and learnability evaluation models are also designed for general mobile applications [15]. They do not capture the limited conceptions of time and understanding that affect children as they interact with mobile applications. [14] Notes that "They lack one or the other criteria important for this area". This makes it challenging to test and evaluate the effectiveness of mobile applications for children.

To address the raised issues, the rest of this paper is organized as follows: Section 2 presents a discussion of related work in literature. Section 3 presents the proposed model that includes Guidelines, Goals, Questions and Metrics. Section 4 is a Case study followed by Results and Discussion in Section 5. Section 6 covers conclusion & future work.

2. RELATED STUDY

The literature on how to measure and evaluate usability and learnability is limited in the area of mobile applications [16], [13]. It is even more scarce when the applications are made for young children [17]. There are fewer guidelines on how various definitions of the usability factor, rules, and criteria are related, and even on how to measure the usability of mobile applications [18]. According to [15], the usability and learnability evaluation of mobile applications has not yet touched the accuracy level of other web-based applications. Nevertheless, a number of mobile evaluation models and methods have been introduced in literature to measure and evaluate the mobile apps. These models are, however, more general meaning that they may not be directly applied to some specific mobile applications.

[19] Introduced a usability measurement model based on a review of empirical mobile usability studies. The usability dimensions proposed in the model are quite comprehensive, though they lack appropriate descriptions on which usability

dimension is to be chosen for a specific mobile application. The model also lacks supporting metrics for each dimension and guidelines for choosing suitable dimensions for a particular mobile application.

While attempting to address the challenges facing the evaluation of mobile application [13] developed a usability model that considers four contextual factors: user, environment, technology and task/activity. This usability evaluation model contains ten dimensions for measuring the usability of mobile applications. However, though the model is well equipped with relevant dimensions, it lacks adequate descriptions on how it can be used to evaluate a specific mobile application, like an app for children, since it was designed for general mobile applications. The model did not also provide supported metrics for each dimension to support convenient and effective usability evaluation approach particularly for a defined mobile application.

Another common model in the literature is the PACMAD usability model (People At the Center of Mobile Application Development) which has two versions PACMAD 2013 by [20] and PACMAD 2015 by [21]- an extension of the former.

The aim of PACMAD 2013 was to extend the existing usability models, such as Nielsen's or the ISO to the context of mobile applications. The model has seven components- Effectiveness, efficiency, satisfaction, learnability, memorability, errors and cognitive load. This model, however, just like the others lacks guidelines and metrics related to chosen dimensions. The 2013 version was also not evaluated to examine its accuracy for mobile applications.

The extended version, PACMAD 2015, filled the gaps above by extending PACMAD 2013 to include relatively low-level metrics in addition to usability attributes. This extended version comprises 21 metrics. It used GQM guide to develop usability metrics matching those metrics yielded from literature. Two evaluation instrument task list and user satisfaction questionnaire are used to collect objective and subjective data for complete usability evaluation of the extended PACMAD. The model is however still general, not touching on anything regarding the evaluation of mobile applications for children.

A more recent model that is relevant to children applications was developed by [17], "A measurement model based on usability metrics for mobile learning user interface for children". The model consists of guidelines, usability characteristics, goals (interface design criteria), questions, usability metrics and two evaluation instruments (A task list and a satisfaction questionnaire). It was validated by applying the proposed metrics and evaluation instruments in a usability study conducted on two android educational apps for children. Though the model is more relevant to children compared to the others, it focuses exclusively on evaluating the interface of mobile educational applications for children. It is not broad enough to accommodate guidelines and metrics suitable for other types of children mobile applications like gaming and entertainment apps. Moreover, the goals presented in the model only focus on interface design.

From these related works, the general observation is that, most of the existing design guidelines and evaluation models cannot be relied upon when designing and evaluating applications for young children as these apps are different both in terms of features and functions when compared to any other general app.

3. THE PROPOSED LEARNABILITY MODEL

Learnability is often a complex quality concept. A model is, therefore, necessary to specify its quality requirements, identify its components and understand them better. To extend and address some of the shortcomings of the existing mobile evaluation models, this study presents a comprehensive learnability evaluation model for children mobile applications. It consists of mainly two sections. The first section presents a review of synthesized design guidelines suitable for apps designed for the target users. A thorough analysis has been done to select only the relevant guidelines, resolve the conflicts and rephrase the unclear ones.

In the second section, the Goal Question Metric (GQM) approach is used to develop questions and metrics for learnability evaluation of the applications. The GQM is a goal-driven method for developing and maintaining a meaningful metrics program. It was developed by [22] and is based on three levels; Conceptual, Operational and Quantitative levels. The approach brings success for the reason that it is adaptable to many different environments [18]. It can possibly be extended to measure usability and learnability guidelines by providing metrics for the guidelines.

The conceptual level entails identifying the goal. In our case, the goal represents the overall aim of the learnability evaluation. The design criteria under consideration in this research act as goals for the GQM. They are General Interaction, Graphical User Interface, Navigation & Search, Multimedia & Text, Content & Engagement, Feedback Adequacy, and Consistency. At the second step, operational level, the goals, and guidelines are used to formulate a list of questions which when answered will indicate if the goal has been achieved. The questions developed constitute the basis for quantitative metrics definition. This study ensures that the questions formulated can easily be answered by the targeted user group.

The last step, quantitative level, involves the development of a set of metrics in order to collect data to answer each question in a quantitative way. Metrics usually represent some sort of measurement as to whether or not we have achieved a certain criterion. The metrics developed are both objective and subjective as not all created questions can be answered objectively. As such, some of the questions will be answered subjectively using a questionnaire to assess user satisfaction.

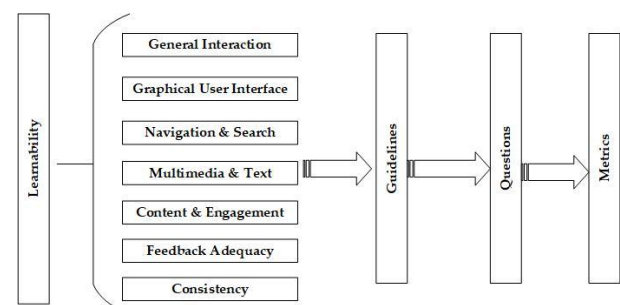


Figure 1. Learnability Model

3.1 General Interaction

When designing and developing mobile applications for young children, it is important for the app interfaces to take into consideration the fact that, these users might not yet have completely understood conventional concepts. The actions of any of the features on the app should at-least map directly to their actions in real world. If some styles and features are not intuitive, some of the children may require extra training with others unable to grasp how the interaction works. The application should thus be developed in a manner that gives children the ability to define their experiences while being in control of the interaction.

3.1.1 Guidelines

1. Make sure every feature and interaction tool is visible and works.
 Many features in an app interface do not necessarily qualify it to be usable. An app can be more usable while having fewer features that all work perfectly, rather than including many of them, with some not working or a level above the intended user group. Avoid screen notifications like "The page is under construction" when designing for children as this group will expect everything to work and work well.
2. Ensure that the interaction tools such as images/icons and buttons reflect if they have been used; using for example different color, size, shape or even pop up messages. This feature may help children to understand what relationship exists between their actions on the screen and the expected outcome.
3. Strive to ensure that the need to type in the mobile app is as minimum as possible. Adults find it uncomfortable to type in a mobile app, meaning it can be more challenging for young children. It is often error prone.
4. Show current interaction state (Users next action should be visible right on the screen). Ensure that the next required action is quite clear to the user. This can be done with effective visual hinting using intuitive icons or graphics.
5. Children learn from examples. Show them a demo: What they learn, they retain. With this quality in mind show them how to perform tasks on the app once and they will most likely not need help again throughout.
6. Create immediate success.
 Children demand fast applications. They normally have little patience for any application that takes a lot of time to load or accomplish tasks.
7. Let the children be in control of the application by allowing them to use it at their own convenient pace. Do not force them to follow a strict process. For instance, let it possible for them to use shortcuts. Allow them also to skip the app on-boarding phase if they are aware of the introductions and instructions. Additionally, ensure that they are aware of the likelihood or possibility to skip them.
8. Make the application interactive; Children love an application that they can interact with by talking to it and it talking back to them. If it is an educational application, the talk-back aspect can enhance the learning process by

changing the traditional classroom setting into a friendlier learning environment.

9. Make use rewards efficiently to promote continuity in use and learning.
 Rewards may be simple "Great job" messages, audio cheers, a badge or a sticker, etc. Points can as well be used for doing various things on the app, e.g. showing a leaderboard in terms of where they stand in the overall rankings etc.
10. If the application is purposely educational, provide occasional entertainment diversions that may keep children more engaged and motivated during learning of tasks. For instance, they find humorous multimedia diversions very enjoyable.
11. Be cautious of promotional elements which attract too much attention. Generally, avoid much advertisements in children applications. Any On-screen interventions should be supportive rather than distracting. Enable Ad-blocks so children won't get distracted with inappropriate information.
 Distinguishing between content and adverts may not be easy and straightforward for children. They regard adverts as important and relevant application elements. For instance, they will especially tap on adverts where the banner contains popular characters or where it is seemingly cool.
12. Avoid making registration a must for these applications to be used; but if it cannot be avoided completely, allow the user to skip sign up and let them be able to sign up later.

Table 1. General Interaction Questions and Metrics

Goal: General Interaction	
Questions	Metrics
Is the application UI easy and intuitive to use?	Time taken on the first attempt Number of tasks successful in the first attempt Number of mistakes while learning to use the application
How much time does the application take to load tasks?	Time taken to load tasks Rating scale for loading time
Does every feature an interaction element work perfectly as expected?	Number of features not working correctly
Is it simple to key in-in data?	Time taken to key in data Number of errors while keying data Time taken to recover from errors
Does the UI provide useful demonstrations to help children understand an activity?	Number of users who can complete tasks without help Rating scale for usefulness of help demos
Does the application protect	Number of accidental errors

against errors in user actions?	during interaction with the application
How much time and effort is required for completing a given task?	Time taken to complete a task Rating scale for task effort
Does the application obstruct children with promotional content?	Number of distracting adverts during task performance

The metrics in red are Objective, The rest are Subjective

3.2 Graphical User Interface (GUI)

The GUI plays a key role in how children and users, in general, perceive an application. Children, notably, like colorful animated designs with simple text and clear navigations. The metrics on GUI measure to what extent a given user interface can be usable, attractive, and satisfactory for the specified users to effectively achieve particular objectives.

3.2.1 Guidelines

1. Reduce cognitive load by making use of more graphics and less Text.

Cognitive load in an application may be characterized by too many features, too many options to choose from, too many questions to answer, or even too much information to read and understand. Therefore include only the most essential elements.

2. Design Finger-friendly Tap-targets.

Due to their small and tender fingers, young children have difficulty targeting small objects on the screen. Thus make the objects simple and big enough so that they're easy for them to tap. Also, ensure that elements aren't located too close to each other so as to prevent false input.

3. Allow customization and personalization.

Let the application be configurable as per children's interests. For example, colors, background images, size of the font, type of the font etc. should be modifiable based on their needs.

4. Provide aesthetic, intuitive, attractive and organized design.

This can be achieved by ensuring that; the font style and size are appropriate; use of bright colors for children, colorful and animated buttons, and a clear consistent screen layout.

5. Children prefer animated colorful characters, icons or images as opposed to static ones. The animations help to illustrate the effect of choosing that particular icon, while also bringing about entertainment. These users also like it when interactive elements can "come alive" when tapped.

6. Use colorful graphics and intuitive UI to make the app engaging and easy-to-understand.

Graphics need to be recognizable, appropriate and relevant to the layout or intended objective. The colors

used should be pleasing to children. For example, gaming apps can have bright, lively colors with more graphics, whereas for educational apps, design to allow easy reading, matching and search capabilities.

7. Add good visual affordance (indications of elements use and how they are to be used), on all interactive elements like images and buttons. Show also task related clues/hints.

Allow children to be able to correctly predict how an interface element will behave by just looking at it. Lack of perceived affordance, such as overly flat graphics may cause the users to overlook them and thus miss important features, they would otherwise have followed.

8. Use language, gestures, and concepts that are appropriate and familiar to children. The icons and symbols used should be familiar and matching to their meaning in the physical world.

They must be relevant and content-specific to the information or function they represent. Resist from using images of outdated objects such as floppy disk, typewriter etc. that may not be recognizable to today's five-year-olds.

9. The arrangement of components must be consistent and simple for the whole application.

10. Allow integration with 3D touch technology to make the experience even more interactive

Table 2. GUI Questions and Metrics

Goal: GUI	
Questions	Metrics
Do buttons and icons show clickability affordance so that children can easily recognize them?	Number of icons/buttons recognizable on first attempt Number of task related clues/hints
Does the UI provide finger friendly tap targets?	Number of mistakes committed by tapping the wrong button/icon
Can the application UI be personalized or customized per child interests?	Number of options for personalization/customization Failure for using personalization/customization options
Is it clear what different features of the application stand for?	Number of unclear and ambiguous features
Is the UI design aesthetic and attractive to children?	Rating scale for attractive interface design
Are children satisfied with the graphics and animations used in the UI?	Rating scale for icons/images, interface color and graphics

The metrics in red are Objective, The rest are Subjective

3.3 Navigation and Search

The navigation aspect, is one of the basic elements of a great user experience. To achieve it, according to [23] "every action or piece of information should be easily communicated and executed".

The navigation must be discoverable, accessible and take little screen space. It should also be able to complement the search technique.

Concerning search, children should be able to access and search an element of interest in the application with as little effort as possible. That means few taps, little scrolling, and zero page loads if possible.

3.3.1 Guidelines

1. Provide a clear and consistent main menu. Don't hide menus on individual pages because it might confuse or disorient young users.
2. Make it possible to use the application in either portrait or landscape orientation.
3. Show the users where they are in the application, where they can go, how to get there, and how to go back to their starting point. Use intuitive graphics and icons to achieve this.
4. Avoid designing an interface that requires a lot of scrolling.

Children interact with what is visible on the screen, therefore, strive to provide a proper interface that shows just everything the child needs so as to interact and learn.

5. Use standard navigation and search schemes such as Tab bar (for iOS) and Navigation drawer (for Android). Many children are familiar with these common conventions and use them easily. Avoid hidden navigation such as gesture-driven because children will have a hard time finding it or figuring it out.
6. The search icon and back icon are very important navigation options. Place them where they are prominent and easily accessible. Don't make kids look for these options.
7. Create excitement about searching and make the search results easy to comprehend.

Children need interfaces that inspire them to search, otherwise, they will never bother to. Many may be unfamiliar with the tools available, but more importantly; many may not understand the possible content that awaits them if it isn't easy to comprehend.

8. While implementing search use the auto-complete feature to allow fast searching.

Table 3. Navigation and Search Questions and Metrics

Goal: Navigation and Search	
Questions	Metrics
Does the UI provide a consistent navigational menu suitable for children?	Rate of success/failure when navigating

Is it easy for children to navigate across the UI?	Number of mistakes resulting due to unclear navigation
Is the screen orientation of the application effective when performing all tasks?	Rating scale for screen orientation
Does the application indicate easy scrolling if a lot of information is present?	Mistakes committed as result of children's inability to scroll Rating scale for easy scrolling
Can children be able to easily locate and use the search/help icon?	Time taken to locate and use the search icon Number of mistakes while searching
Can children be able to comprehend the search results?	Rating scale for comprehending search results

The metrics in red are Objective, The rest are Subjective

3.4 Multimedia and Text Usage

Multimedia aspects like sounds, animations, graphics, and other art based attributes play a significant role in the success of children's software applications

When used effectively, they enhance their learning experience and speed the interaction process.

3.4.1 Guidelines

1. Use motion and sound on important elements on the screen to attract child attention and engage them.

Proper tunes and animation make applications even better perceived by children as they find them extremely engaging. The animations and sound effects often excites children and encourages them to stay longer with an application.

2. Make introduction animations short and interesting.

Animations that are short (10 to 20 sec) and meaningful (funny, surprising, intriguing and enjoying) work best for children.
3. Allow different modes of communication between the user and the application. For example audio and text modes can be used simultaneously. This can end up making the application accessible to both reading and pre-reading children.
4. When interacting with a multimedia clip, show the users the status of multimedia playtimes. Present progress to completion and how long it takes to play the entire multimedia clip.
5. Allow the children to control the multimedia clip. Provide an explicit skip feature such as skip button for all clips/movies.
6. Use only understandable and brief to the point text. Minimize the amount of text on the screen and consistently maintain a high level of readability.
7. Use simple and relatively large fonts.

Avoid decorative wording that makes it difficult to understand different choices. The decorative or fancy wording in interfaces confuse children and prevent them from understanding the available choices.

8. Avoid animated texts.

Special effects on texts may cause problems to children. For example when the animated texts are too slow, too fast or when the texts and objects are superimposed.

9. Provide a good contrast between the text and the background. Contrast is very important for children who are beginning readers.
10. Avoid providing instructions in blocks of text. Place easy to find links to brief text explanations whenever the user might need or want instructions.

2. Design interaction elements that children can understand and identify with. Children love elements that appear to be animated.
3. To make children more engaged in the application, let them be in full control of the interface. Young children are exploratory and will enjoy influencing various elements while seeking out all the possible ways they can interact with them. The more they interact with the design elements, the more engaged they become, regardless of how minimal the interaction is.
4. Tasks on the app should be easy for children to handle. If they are too difficult, the children may feel bored and avoid using the application. Provide in the app an option to adjust the level of difficulty for children of different ages. Include an option allowing them to skip certain challenges if they get stuck.
5. Avoid unnecessary information. Unnecessary information in the application can decrease children's focus and attention and also confuse them.
6. Motivate children by providing interesting rewards for each correctly solved task. Motivation can be done using stars, points or any other type of image accompanied by a pleasant melody or a congratulatory message. Points or grades collection add the sense of competition to the process of learning
7. On top of motivating them, Praise the children for the value of their actions. This improves their confidence and may help them to perform subsequent tasks better.
8. Reduce the learning curve of using the system by including onboarding if necessary.

Table 4. Multimedia and Text Usage

Goal: Multimedia and Text	
Questions	Metrics
Does the application provide adequate visual and audio assistance?	Number of voice assistance options in a task
Are the multimedia elements (e.g. animations, graphics, sound and video) appropriate for children?	Number of multimedia elements the user can identify on first attempt Rating scale for multimedia elements usage effectiveness
Can children be able to control the pace of multimedia clips?	Rating scale for satisfaction while playing clips
Does the application provide easy text readability for children?	Rating scale for text readability
Is the text usage (font styles, size and color) appropriate for children?	Rating scale for text usage satisfaction

The metrics in red are Objective, The rest are Subjective

3.5 Content and Engagement

For an application to garner the attention of children, the content should be engaging. Effective content and Mobile app engagement are two metrics that provide genuine insight into the success of an application. Ineffective content and Low app engagement are a recipe for failure, while high engagement and retention equal to the opposite. The success of an application can be determined by the user engagement and activity on it.

3.5.1 Guidelines

1. Use appropriate content, language and familiar concepts.

Young children are excited by content that is funny and entertaining. Additionally, the app interface should be unobtrusive and let children get to the content as simply as possible.

Table 5. Content and Engagement

Goal: Content and Engagement	
Questions	Metrics
How much time do children spent on the application by themselves?	Time spent on the app(session length) when child is alone
Does the application provide exciting rewards to keep children engaged?	Frequency of rewards Rating scale for engagement through rewards
Is the app content satisfactory, pleasing and appropriate for children?	Rating scale for appropriate content
Does the app provide useful and interesting learning activities for children?	Task completion rate

Does the application provide different task difficulty levels?	Number of tasks with different difficult levels Rating scale for engagement through difficulty levels
Are concepts used familiar and matching to children mental models?	

The metrics in red are Objective, The rest are Subjective

3.6 Feedback Appropriateness

When interacting with an application, users rely on feedback to inform them that they are progressing towards the desired objective. The immediacy of the mobile devices and the short-time period interactions which users have with these devices means that feedback must be delivered faster and more regularly in order to keep users engaged.

3.6.1 Guidelines

1. Task response time must be quick. Children are going to become frustrated if they don't receive some feedback on their action as soon as it's possible or relevant to do so.
2. In case it is not possible to offer instant response, the application should provide a clear indication that the task is in progress. This can be done using a clever and entertaining animation to retain the attention of the children while waiting. The Progress bar or spinning wheel may not work well with children as they sometimes feel as though they've been waiting for so long, even if it has only been for a few seconds.
3. To avoid confusing the children, response times for identical or similar tasks should be comparable.
4. Provide visual and auditory feedback to children whenever they do anything on the application. The feedback content should be easy for the children to understand. The way or format in which the same is given should also be suitable to the intended group and to the context under which the application is used.
5. Provide feedback in such a way that it does not interrupt the user's current work-flow. Notifications should not interrupt the user's current activity unless absolutely necessary and it should be easy to dismiss if the user wants to ignore them.
6. Make it possible to manage audio feedback by providing an option to turn it on/off
7. Keep the notifications and alerts to a minimum and use them only where they add genuine value to the user experience. They should always include valuable data and prompt meaningful actions. Alerts

and feedback should be kept as simple as possible with clear and easy to understand choices generated from them. (Pay particular attention to button labels).

8. Use feedback to validate and explain why an action was invalid. Telling a child that an input is not correct is not a high-value activity. Showing them an example of a correct input is.
9. Strive to use feedback format that recognizes or mentions the child's name. This captures their attention. Children get thrilled when they realize that the application knows some details about them. Therefore use the information you know about them to offer surprising feedback.

Table 6: Feedback Appropriateness

Goal: Feedback Adequacy	
Questions	Metrics
Does the application provide visual or auditory feedback to children whenever they perform a task?	Rating scale for appropriate feedback
Is task response time appropriate?	Task response time Rating scale for appropriate response time
Is the way the application responds to user actions consistent at all times?	Difference in response times
Does feedback provided interrupt the user's current workflow?	Number of times user is interrupted while performing a task.
Can children be able to control audio feedback by turning on/off?	Rating scale for child freedom to control feedback

The metrics in red are Objective, The rest are Subjective

3.7 Consistency

Consistency refers to having similar operations and similar elements for achieving similar tasks. According to [24] "it is one of the most important aspects of measuring user interface design principles". Children rely on a consistent experience. And like adults, they would be annoyed if unexpected or random elements ruined their experience.

A consistent representation enables a user to recognize elements and anticipate the next action thereby speeding up the learning curve for new products and services that a user has yet to explore.

3.7.1 Guidelines

1. The UI elements of the design interface (such as graphics, fonts, colors etc.) should be consistent at each point, as should the interaction and content. The content should be consistent in tone, mood, quality, and quantity.
2. "Make it very clear to the user what the next required action is. The more visible the available functions are, the better users will be able to perform their task.

Interaction and input-output behavior should be consistent within a system as well as across systems. The user should be able to extend knowledge of specific interaction within and across the application to other similar situations" source[25]
3. "Changes to the internal state of the system must be visible so that users can associate with operations that caused them" source [25].
4. "Metaphors should draw on children's existing knowledge so that they can easily see what to do and predict the outcome of their actions" source [25].
5. Limit the number of ways actions and operations are represented, ensuring that users do not have to learn new representations for each task. Follow platform conventions that allow children to complete new tasks without having to learn a new tool-set.
6. Do not deviate a lot from design conventions and standards as children just like adults tend to apply rules they've experienced outside the application, bringing in a set of own expectations.
7. Make input-output behavior easy and understandable. It should be consistent within the application and across other similar applications. "Children should be able to determine the effect of future action based on past interaction history" source [26].

Table 7: Consistency

Goal: Consistency	
Questions	Metrics
Are the UI elements of the design interface (graphics, fonts, colors) consistent at each point?	Rating scale for consistency of design elements
Can children be able to tell what is likely to happen on the app based on their past interaction?	Rating scale for familiarity of interface
Can children be able to link metaphors used, to what they represent on the physical	Number of metaphors that children cannot identify with

world?	
Does the application UI deviate from conventional design standards?	Rating scale for deviation from other design standards

4. CASE STUDY

A case study was conducted involving young children (class 2 and 3 pupils in Kenya) using a learning application on the tablets provided by the government under the OTPC initiative in Kenya. The actual study involved twenty children and one teacher who acted as an expert during the data collection period.

It was conducted in three phases.

1. In Phase 1; the participants were required to answer some demographic questions. From the questions, the aim was to get information about their gender, age, class and also their level of experience while using mobile phones and tablets. To maintain their privacy, their names were not recorded.
2. In Phase 2; the participants were required to perform a series of tasks using the tablets with the aim of collecting quantitative data to answer the objective metrics. The tasks carried out are listed in the next section below
3. In Phase 3; Interviews were conducted shortly after finishing up on the tasks so as to gauge the participants' level of satisfaction with the application. This was done to obtain qualitative data which would help in answering the subjective metrics. The responses were measured on a 5-point Likert scale with responses varying from strongly disagree to strongly agree scale labels.

Task List

Each participant (child) was asked to perform each of the following four simple tasks.

1. Identify the icons in the main menu that they were familiar with
2. Match a picture to its name through drag and drop
3. Type in the plural of a set of words
4. Choose and type the correct word in a pool of words to complete a sentence

For task 2, 3, and 4 the following objective measures were recorded.

- Task Completion time
- Data Entry time
- Response Time
- Number of Errors
- Task Completion rate
- Number of voice support.

User satisfaction questions, in form of a study questionnaire, were then used right after, to interview the children so as to get their opinion about the usability of the application.

5. RESULTS AND DISCUSSION

5.1 Objective Measures

Table 1 below presents the objective measures results that have been derived from the recordings during the execution of tasks.

Table 8: Objective Measures

Objective Metric	Adult	Children		
		Minimum	Maximum	Mean
Task completion time(sec)	120	283	345	310.75
Data entry time(sec)	55	111	127	121.10
Task response time(sec)	5	7	10	8.10
Number of errors	0	0	3	1.45
Task completion rate (%)	100	100	100	100
Number of voice support	0	0	0	0.00

The table gives a summary of the minimum, maximum and means of the data collected for each objective measure from the children participants. The data takes into consideration the average of the three tasks under examination collectively. The data from the teacher (adult/Expert) is also presented to help in making comparisons.

5.1.1 Interpretation

This interpretation is based on how the participants fared on their tasks collectively. The task completion time and data entry time(s) have a considerable difference to the adult's data. The children averaged 310.75 sec (over five minutes) to complete the tasks and 2min for the task that required data entry. In contrast, the teacher averaged two minutes to complete the tasks and less than a minute to enter data.

The children also committed at least an error on average and received no voice support for all the tasks. The task response time is varying because feedback was not instant and participants had to scroll to locate and tap a "CHECK" button after which the results of the tasks would be revealed. Difficulty in scrolling led to the time lapse between completing a task and getting feedback on whether one is correct or wrong.

The task completion rate was at 100%. This has an indication that the children have the ability to perform tasks using the

application to completion when given ample time regardless of whether they will get all the tasks right or wrong.

5.2 Subjective Measures

This section presents the results obtained after analyzing the responses of participants in the study questionnaire.

Table 2 below shows the mean and standard deviation of the subjective measures. The responses were on a scale of 1-5; with 5 meaning Strongly Agree, 4- Agree, 3- Neutral, 2 - Disagree and 1 - Strongly disagree

Table 9: Subjective Measures Results

Satisfaction Measure	Mean	Std. Deviation
General Interaction	2.66	0.90
GUI	3.50	0.46
Navigation & Search	3.04	0.51
Multimedia & Text	3.28	0.60
Content & Engagement	2.83	0.56
Feedback Appropriateness	2.55	0.40
Consistency	2.41	0.28

5.2.1 Interpretation

The mean or average of the highlighted design criteria is recorded. A higher mean score implies that users were highly satisfied whereas a low mean score implies the opposite.

The results from the table indicate that participants were more satisfied with the graphical user interface of the application than on the other criteria, though it only averaged a mean of 3.50 which translates to a Neutral score. Navigation and search completeness and Multimedia and Text also average a neutral score implying that the participants had an ambivalent opinion on these design criteria on the application.

The general interaction, Content & engagement, feedback appropriateness, and consistency scored an equivalent of "disagree" score, meaning that participants probably felt not quite satisfied the application on these areas. Therefore there is a need for improvement of these design aspects.

5.2.2 Graphical Representation of Participants Rating per question

In addition to the analysis from the table, this section presents a graphical representation for each design criteria and satisfaction question on how the participants gave responses for each question.

5.2.2.1 General interaction

The graph on general interaction below shows the responses to questions on how the participants were satisfied when generally interacting with the application. The actual

questions which in the graph are coded as C1.1-C1.6 are as follows.

- C1.1 - I found it easy to use the application
- C1.2 - It is easy to complete tasks without any help
- C1.3 - It was simple to key in data
- C1.4 -The app provides task demos that show how a task is done
- C1.5 - I understand what all the icons in this app stand for
- C1.6 - The application takes a lot of time loading tasks.

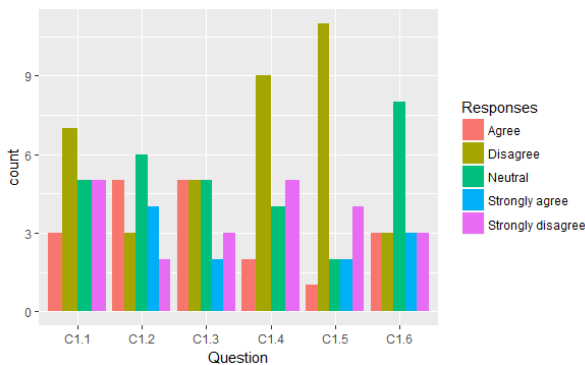


Figure 2. General Interaction rating

The results on general interaction point out that children did not find it easy to the application on their own. Data entry was not easy for most of them. Additionally, the app did not provide any task demos to help children understand how to perform tasks. Many of them still had problems in identifying what some of the icons represented.

These results are comparable to what [4]observed while also evaluating the interface of mobile application with children. Their observation indicated that "most of the children found it difficult to interact with menu buttons and to access the next screen. They were not sure what to do on the main screen. They had to seek help from a facilitator. There was no indication that the screen was interactive as the icons and buttons lack affordance that they are click-able or audible".

Moreover "there was no help to demonstrate the practices or interactions that children were required to do in each screen". It would be helpful for children to learn on their own if there were proper examples on each screen for the children to follow. This speeds children's learning as they need not go through trial and error nor self-explore.

5.2.2.2 Graphical User Interface

This graph shows the respondents satisfaction with the graphical user interface of the application. The question codes' statements are as follows:-

- C2.1 - The main menu for this application is attractive
- C2.1 - The organization of information on the screen is clear and consistent
- C2.3 - The main menu contains a lot of information(crowded/cluttered)
- C2.4 - The buttons and icons are easily recognizable

- C2.5 - The buttons and icons are large and finger friendly
- C2.6 - The colors used in this application are very attractive.

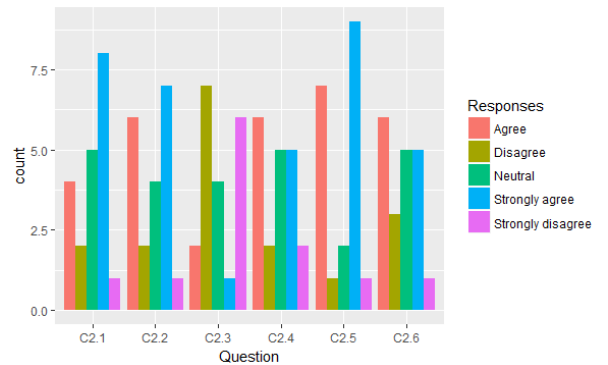


Figure 3. Graphical User Interface rating

From these results, we make observations that most of the children found the main menu of the application being attractive clear and consistent. The icons and buttons used were easily recognizable and finger friendly. The colors used were also found to be attractive. From this we can infer that the apps graphical user interface elements are appropriate to the young children.

The application GUI elements are consistent with the findings of [1] who indicated that to capture children's attention, "use colors and backgrounds that are pleasing to the age group. For kids make use of bright, lovely colors with more graphics". Additionally [27] observed that children prefer seeing many patterns and colors on screen and more interested with animated buttons.

5.2.2.3 Navigation and Search

The graph shows the respondents satisfaction with the navigation and search attributes of the application. The questions codes statements are shown as follows.

- C3.1 - The orientation of the screen is comfortable while performing a task.
- C3.2 - It was easy to navigate back and forward across the application
- C3.3 - Scrolling through the application is easy
- C3.4 - It was easy to locate and use the search and help icons
- C3.5 - It was difficult to understand the search and help results.

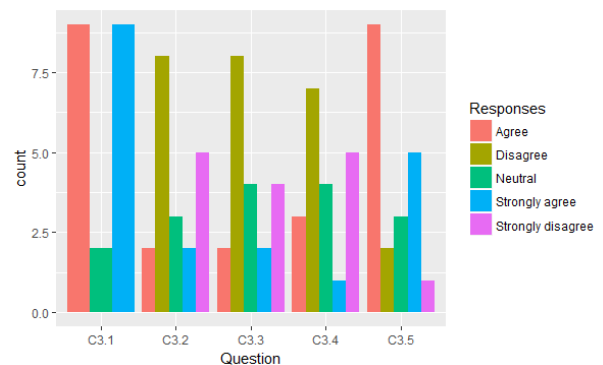


Figure 4. Navigation and Search Rating

From this graph, we can deduce the following:- That the participants were comfortable with the screen orientation of the application while performing tasks. However, it is observed that it was not easy to navigate and scroll across the application for most of the participants. They also could neither identify the search and help icons nor understand how to search effectively.

Similar to these findings,[17] while evaluating two educational mobile applications observed that both apps showed poor usability regarding help, tutorials, navigation, voice instructions and error messages. This trend indicates that there is need to improve the navigation, search and help attributes in the context of mobile applications.

5.2.2.4 Multimedia and Text

The graph shows the respondents satisfaction with the multimedia and Text elements as used in the application. The questions code statements are revealed as follows:-

C4.1 - I found the pictures and animations very interesting

C4.2 - It was easy to read the texts and numbers on this application

C4.3 - The size of text and numbers on this application were large enough

C4.4 - The music and sounds in the application were too disturbing

C4.5 - The application provides useful voice instructions

C4.6 - I was able to turn voice instructions On/Off.

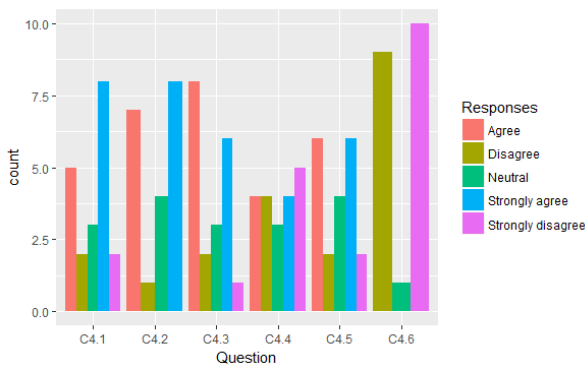


Figure 5. Multimedia and Text Rating

It can be reported that the participants found the pictures and animations interesting to them as shown from the responses. The size of text and numbers in the application can also be said to be friendly to them as it can be observed that they were large enough and easy to read. However, there are mixed reactions concerning the music. Initially it captures their attention towards the tasks, but still somehow disturbing as they could not be able to turn the music on/off.

Multimedia attributes play an important role in children's interaction with mobile applications. As reported by [28], the

musical experience is very important in the context of IT design as

1. It is a natural part of children's life and education
2. It is comprehensive and has an influence on all sensations and imaginations
3. It enriches and supports children creations and
4. It inspires and supports children participations.

5.2.2.5 Content and Engagement

The graph below is an indication of how the content in the application was satisfactory to the participants and how engaged they were while performing tasks in the application.

The questions codes statements are shown below:-

C5.1 - The learning content in this application is satisfactory

C5.2 - The learning activities are interesting and enjoyable

C5.3 - The concepts and learning activities are familiar

C5.4 - I received exciting rewards after completing a task

C5.5 - The tasks have different difficulty levels.

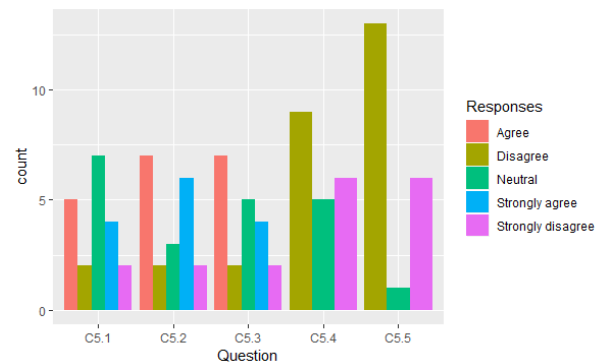


Figure 6. Content and Engagement rating

The participants felt that the learning content for the tasks they performed was satisfactory to them. The tasks were generally interesting and the concepts familiar to what they are accustomed to. However, they received no rewards from the application upon completing the tasks which is an area of improvement given that children need to be congratulated for every task they perform.

This findings concerning rewards are in a way similar to ones by [8] who observed that 83% of the children in a survey they conducted were of the opinion that "it would be a good idea to receive a prize after every success in the application they use to play or study, whether in the form of stickers, asterisks, or any other kind of bonus points".

5.2.2.6 Feedback Adequacy

The graph shows how the participants were satisfied with the feedback they received from the application as they performed tasks. The question codes statements used in the graph are given as follows.

- C6.1 - I receive feedback after completing tasks on whether I am right or wrong
- C6.2 - When wrong the app gives error messages that clearly tell how to correctly perform the task
- C6.3 - The response time after tasks is slow
- C6.4 - Some error messages interrupt me as I perform tasks
- C6.5 - I get responses faster in some tasks compared to others.

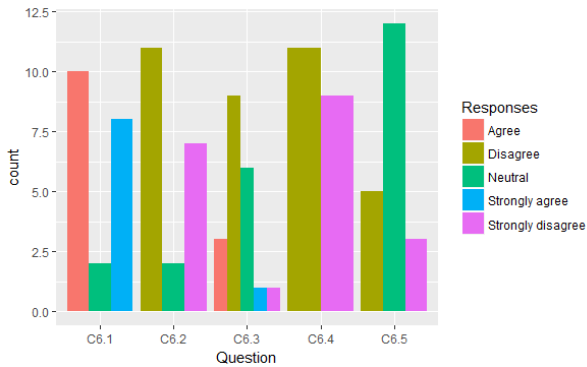


Figure 7. Feedback Adequacy rating

Most respondents agree that they receive feedback after completing a task on whether they are right or wrong. However, the feedback does not clearly show how to perform the task if one gets it wrong in the first attempt. All participants said that they didn't get interrupted by error messages as they performed tasks.

The inference from this observation is that the participants were not satisfied with the way in which they received feedback while performing tasks. The applications mode of relaying feedback on incorrect answers is inconsistent with what is suggested by [29] that "a wrong answer should be an opportunity for a learning moment." The use of audio and visual feedback should be encouraging and incremental. This article suggests that wrong answer feedback should typically be given within 3 scaffolded levels".

1. First Wrong Answer: Identify a wrong choice and offer encouragement. Example: "That's not it. Try again!" !
2. Second Wrong Answer: Identify a wrong choice, restate the objective, offer a hint, and provide encouragement. Example: "That's not right. You need to find a triangle. It has 3 sides and 3 angles! Try again!"!
3. Third Wrong Answer: Identify a wrong choice, restate the objective, offer a hint, and highlight the correct answer. Example: "That's not right. You need to find a triangle. It has 3 sides and 3 angles! <Triangle highlights> Tap on the triangle!"

"This should be repeated until the correct answer is selected. In some cases, we may suggest moving a child forward if he/she is struggling for a determined period of time".

5.2.2.7 Consistency

The graph shows the rating of how participants felt regarding consistency of various elements of the application.

Question code statements:-

- C7.1 - The texts fonts, colors, background color, and animations are consistent across the applications
- C7.2 - I am familiar with all the images used in the application in the physical world

C7.3 - The main menu of this application looks similar to others I have seen before

C7.4 - I was able to know how the application would respond based on tasks I have done before.

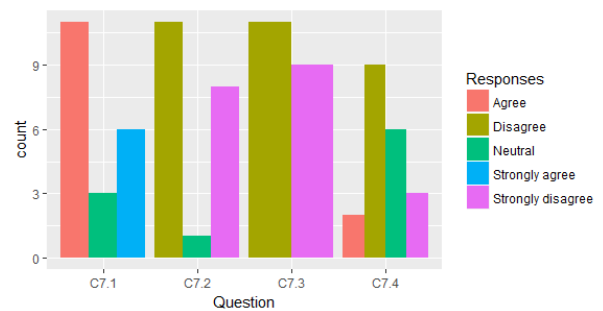


Figure 8. Consistency rating

According to the graph, most elements of the application seem to be consistent across the application. However, most of the respondents are not conversant with all that icons used in the application in the real world. This call for an improvement in this area, to make sure that images and icons used the application are familiar to children in the real world making sure that they can connect their use in the physical world to what they represent in the application.

These finding affirms what [7] suggests that "it is very important to keep design patterns consistent as both kids and adults get annoyed by design elements that seem random and unnecessary". The interactions and feedback should also be consistent so that users will be able to learn how to use the app quickly.

6. CONCLUSION AND FUTURE WORK

This paper focused on reviewing and presenting usability guidelines for children mobile applications and proposing a theoretical evaluation model for the said apps. Most of these guidelines were synthesized from previous research reporting on usability & learnability issues for children mobile applications. They can be helpful to other researchers, practitioners, designers and developers in designing usable mobile applications for young children.

The model serves as a basis for comprehensive learnability evaluation for mobile applications for children. To test the effectiveness of the model, usability testing involving children

was conducted using an educational mobile application used for learning in Kenyan primary schools. The results of the study and the inferences made have been presented in the paper. Not included in the paper but in line with the study is the automation of the Model which may be published later on as future work. Further contributions to this research may include conducting more usability testing using different kinds of applications targeting young children.

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