Towards to Usability Guidelines Construction for the Design of Interactive Mobile Applications for Learning Mathematics

Carlos Andrés Casas Domínguez[1(✉)], David Oidor Mina[1], Vanessa Agredo-Delgado[1,2], Pablo H. Ruiz[1,2], and Deema M. AlSekait[3]

[1] Corporación Universitaria Comfacauca - Unicomfacauca, Popayán, Colombia
{carloscasas,davidoidor,vagredo,pruiz}@unicomfacauca.edu.co
[2] Universidad del Cauca, Popayán, Colombia
[3] Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia
DMAlSekait@pnu.edu.sa

Abstract. There is a wide variety of approaches to establish usability in different types of applications and contexts, in order to achieve effectiveness, efficiency, and satisfaction in users. Given this diversity and the absence of clear rules on how to apply such usability in specific contexts. This paper proposes a set of usability guidelines that provide adequate elements for software development in the specific context of the design of interactive mobile applications for learning mathematics in children aged 6–7, which were derived from existing general usability guidelines, of context analysis and its needs. This paper is intended to show an initial version, where were validated its completeness, suitability, ease of use, and ease of learning, through expert judgment. For this work, a substantial body of research was consolidated using the multi-cycle action research methodology with a three-cycle fork: conceptual, methodological, and evaluation. According to the results, it can be said that the guidelines are complete, easy to learn, moderately usable and moderately suitable; it determines that there is a need to continue improving their description in such a way that they can adequately satisfy the purpose for which they were created, however, we believe that the resulting guidelines represent a good contribution to the usability engineering knowledge field in this context.

Keywords: Usability · Guidelines · Usability guidelines · Design of interactive mobile applications

1 Introduction

In recent years the use of the mobile device (phones, portable audio players, personal digital assistants, GPS (Global Positioning System) navigators, tablets, digital cameras, etc.) has increased considerably, which is why it is important to have methodologies, elements, and tools that allow to carry out specific usability studies for applications developed for this type of devices [1], specifically for applications that were developed to run on mobile phones. The term mobile refers to being able to access data, applications,

V. Agredo-Delgado et al. (Eds.): HCI-COLLAB 2020, CCIS 1334, pp. 275–284, 2020.
https://doi.org/10.1007/978-3-030-66919-5_28

and devices from anywhere. [2], for this reason, to software development of this kind, certain restrictions that the hardware has and the context where it will be used must be taken into account, however, the methods, metrics, and guidelines currently used to define usability have been created for desktop applications or web, which may not be directly suitable or appropriate for mobile environments [3], besides, there is an absence of clarity on how to apply this usability in more specific contexts [4]. One of the main challenges is to identify the additional variables related to the use environment and the context, which can impact the usability of a mobile application so that when designing, these variables can be included [3].

This is why this paper focuses on defining a set of usability guidelines for software development in the specific context of the design of interactive mobile applications for learning mathematics in children aged 6–7 years, which were derived from existing usability guidelines, an analysis of the context and its needs. Taking into account that the field of education is incorporating new supports, tools, or technologies that favor student learning processes [4, 1]. However, each application has its own particularities in relation to human-machine interaction that affects the handling and design of its interfaces, as well as the function and uses they may have in a given environment. [4]. For this reason, this paper intends to show an initial version of the set of guidelines to which their completeness, suitability, ease of use and ease of learning were validated, through the judgment of experts, using the multi-cycle action research methodology with a branch of three cycles. According to the results, it can be said that the guidelines are completeness, easy to learn, moderately usable and moderately suitable; determining that there is a need to continue improving its description so that they can adequately satisfy the objective for which they were created, however, we believe that the resulting guidelines represent a good contribution to the usability engineering knowledge field.

This paper is structured as follows, section two: related works, section three: the methodology that was carried out, section four: validation and finally, section five: the conclusions and future work.

2 Related Work

The objective of research of Videla et al. [5], was to determine the elements, components, and factors that are key when designing interactive interfaces for augmented reality environments, focusing in particular on the development of virtual environments for educational applications. For this study two applications of augmented reality of educational content were carried out and tested and whose purpose was to be a complement to the textbook, which were designed for non-tactile interfaces and in which the use of a Webcam and a computer.

On the other hand, Collazos et al. [6], define a guide to correctly include usability in interactive television, and shows evaluation methods to verify its good design. This work described and structured a set of guidelines that can be followed by user interface designers to achieve services clearly adapted to the interactive environment of television. Similarly, there was a project in the UTM (University Technical of Manabí) that focused on the development of educational applications for mobile devices called Edumóvil. It is a project that was born in the UTM and had as its objective: to improve the teaching-learning process of basic level children through the incorporation of mobile technology

in the classroom [7], It was focused on developing applications for PDAs (Personal Digital Assistant) and cell phones that covers primary subjects, such as Spanish, Mathematics, History and Natural Sciences, this development an application consisting of a collaborative game for the subject of Natural Sciences and a story viewer aimed at the subject of Spanish [7].

From the viewpoint of education, there are projects such as the one defined by Ocsa et al. [8], which aimed to systematize the design and development of m-learning applications through two types of applications, the first one inter-active in comic format about the foundation of the Inca Empire and the second in book format Interactive about the main tourist sites of Peru, which was intended to reduce the complex development of these applications through encapsulations of native code for mobile operating systems, allowing to establish design and development guidelines for high quality mobile educational applications, in addition, to Consider elements of human-computer interaction, user-centered design as the basis for the development of case studies in order to reflect the scope of applications from a pedagogical and technological viewpoint. Similarly, Tello and Yautibug [9], took into account the current influence of Virtual Learning Environments (VLE), where its development and design is of great relevance for its context of use, therefore, they identified and implemented criteria of good usability practices to detect design errors in the VLE of the National University of Chimborazo and thus increase its level of usability.

The previous works show different methods to evaluate usability in various contexts and applications, but none are related to a specific context of usability guidelines for the design of interactive mobile applications for learning mathematics in children from 6 to 7 years old, that is why in this work, a set of these guidelines is proposed to further guide this process.

3 Methodology

This research was developed following the multi-cycle action-research methodology with bifurcation [10] for which cycles were followed: conceptual cycle, methodological cycle, and evaluation cycle.

3.1 Conceptual Cycle

This cycle consisted of carrying out an analysis of the literature, to identify the existing usability guidelines, as well as to gather important information about concepts, design guidelines, guidelines and elements necessary to include usability in this context. This process showed that most of the guidelines were focused on a web context and desktop applications regardless of context, and lacked a clear explanation for their application. For the development of this cycle, the following activities were carried out as shown in Table 1 Conceptual cycle.

Table 1. Conceptual cycle

Number	Activity
1	To collect information in the literature regarding usability guidelines for application design
2	To Identify the characteristics of end-users of interactive mobile applications
3	To analyze the information collected to identify a set of guidelines, rules or elements appropriate for the design of interactive mobile applications
4	To select the relevant information from the previous analysis
5	To select the guidelines that meet the design needs of interactive mobile applications in this context

3.2 Methodology Cycle

This cycle consisted of analyzing the information obtained previously, selecting the useful elements and defining the necessary ones that allowed to create a first version of the guidelines for the context of this paper. Table 2 shows the activities carried out in this cycle.

Table 2. Methodology cycle

Número	Actividad
1	To realize an interview with math teachers, where needs, difficulties and important elements of the specified context are identified
2	To determine if the usability needs of the users were met with the guidelines analyzed in the previous activities
3	To build the usability guidelines that meet the needs not contemplated in existing studies
4	To generate the guide or list of usability guidelines, obtained in the previous analyzes for later implementation
5	To classify usability guidelines according to usability standard 9241-11

For this cycle, a survey was conducted with 9 teachers from the municipality of Puerto Tejada and 1 teacher from the city of Popayan. The survey consisted of 7 open questions, in this way, more than questions, a dialogue was held with each teacher. These questions were developed in order to obtain information on the topics in which the most difficulties are presented among students, the topics that seek to be supported by the application, in the same way, to socialize the idea and see the opinions and ideas of teachers that will help to solve the missing needs that had not been identified.

After analyzing the data obtained, it was determined that the strongest needs in mathematics on the part of the children were in the sum, which is why it was defined as the topic to be treated of the applications to be designed, in addition to defining that

these applications must be used by the child for an approximate time between 10 to 15 min. From the survey, some missing guidelines were also defined in order to meet the unidentified or missing needs related to the context.

As a result of this activity, the definition of a format necessary to describe each guideline is obtained, which contains an identifier, a name, a category, a brief description, the steps to be followed, and an illustrated example of applying the guideline. In addition, the first version of the list of guidelines is obtained with a total of 56.

To improve the first version of the guidelines, the standard 9241-11 of usability is taken into account which contains 3 fundamental characteristics that are: effectiveness, efficiency, and satisfaction [11]. These characteristics were redefined for the context of this work, and each guideline was classified into each characteristic. With this classification, those guidelines that do not comply with any of the characteristics of the standard are discarded and, as a result, we obtain a second version of the list of guidelines, generating a total of 39 (See the list of guideline names on Table 3, see an example of the guideline definition on Table 4).

3.3 Evaluation Cycle

This cycle allows evaluating the completeness, suitability, ease of use and ease of learning of the second version of the usability guidelines. Table 5 the activities carried out in this cycle are shown.

For the development of this cycle, a validation of the guidelines was carried out through a survey aimed at experts in usability, validating its completeness, suitability, ease of use, and ease of learning, for the design of interactive mobile applications for learning mathematics in children aged 6–7 years.

4 Validation

The objective of this validation was to evaluate with experts in usability issues the completeness, suitability, ease of use, and ease of learning of the guidelines developed for the design of interactive mobile applications for learning mathematics in children 6–7 years. This validation was carried out with 6 experts in the area of usability, of which 66.7% have more than 5 years of experience in the area of usability and 33.3% have between 1–5 years of experience.

Each of the experts was given the compendium of the guidelines, in addition to a survey link for validation. The survey had 2 sections, the first one briefly explaining the why and for what of the completion of this survey and the evaluation method which will be conducted according to the Likert scale [12], a second section where the questions were presented in accordance with the 4 categories that are to be validated: completeness, suitability, ease of use and ease of learning.

With the evaluation of the experts, the results of the validation of the proposed guidelines were obtained (See results Fig. 1), these experts provided suggestions for a better interpretation and greater impact of the guidelines on their use, some of the most outstanding opinions by categories were the following:

Table 3. List of guideline names

Guideline title	
System status visibility	Icons
Correspondence between the system and the real world	Character and environment
Control and freedom for the user	Colors
Consistency and standards	Interaction styles suitable for children
Error prevention	Realistic math
Recognize before remembering	Interactivity
Flexibility and efficiency of use	Think like a child
Aesthetics of dialogues and minimalist design	Competitiveness
Help users to recognize, diagnose and recover errors	Foster creativity
Promotion of access to the social environment	Thematic scope
Provision of access to the natural environment	User needs
Attention resources management	Constant evaluation
Management of motivational resources	Required fields
Learning facility	Communication with aspects of the device
Processing capacity	Publication
Security	Dynamic data validation
Capacity (storage and memory)	Pop-up windows
Texts	Confirmation pages
Tabs	Estimated time
Compatibility	

Completeness:

- To include an additional section that refers to when a guideline is violated
- To improve writing and synthesize descriptions in some cases

Suitability:

- No specific guidelines for learning mathematics are identified in children between 6 and 7 years old (only guideline 36 is found)
- There are some guidelines that are generic, even heuristics such as Nielsen's have been included, so they must be filtered and specified more in the context of children and mathematics

Table 4. Guideline example

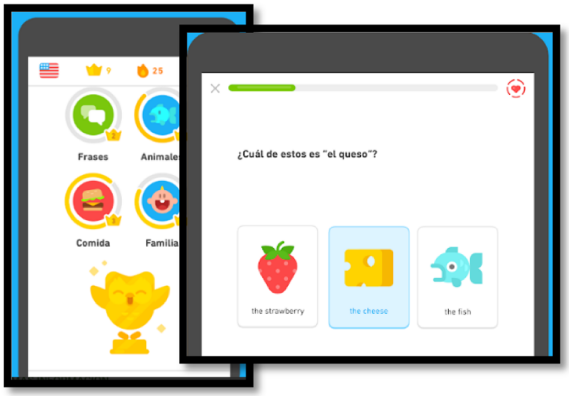
Identifier	11
Name	Provision of access to the natural environment
Category	Pedagogical strategies, content, games, web.
Description	It refers to the incorporation of elements that generate the environment in which the student will perform, and with them, it must be achieved that it identifies the tasks that must be performed in the educational application [1]
Application steps	• To include images that have educational purposes or that help the student's memory [5]. • To include animations for explanatory purposes of some content or concept [5]. • The use of a metaphor that associates a specific function with a representative image is recommended so that the child does not have to memorize them and interact in a more intuitive way.
Example	A clear example is the Duolingo application, an app dedicated to teaching the English language, which uses images that help the user understand and memorize what they want to teach. 

Table 5. Evaluation cycle

Number	Activity
1	To design a mechanism for assessing completeness, suitability, ease of use, and ease of learning of the defined guidelines
2	To perform the application of the evaluation mechanism to usability experts
3	To analyze the results obtained by the experts

Easy to use:

- To define a tool (guide) that facilitates the use of the guidelines, where it is determined when and how to use each guideline

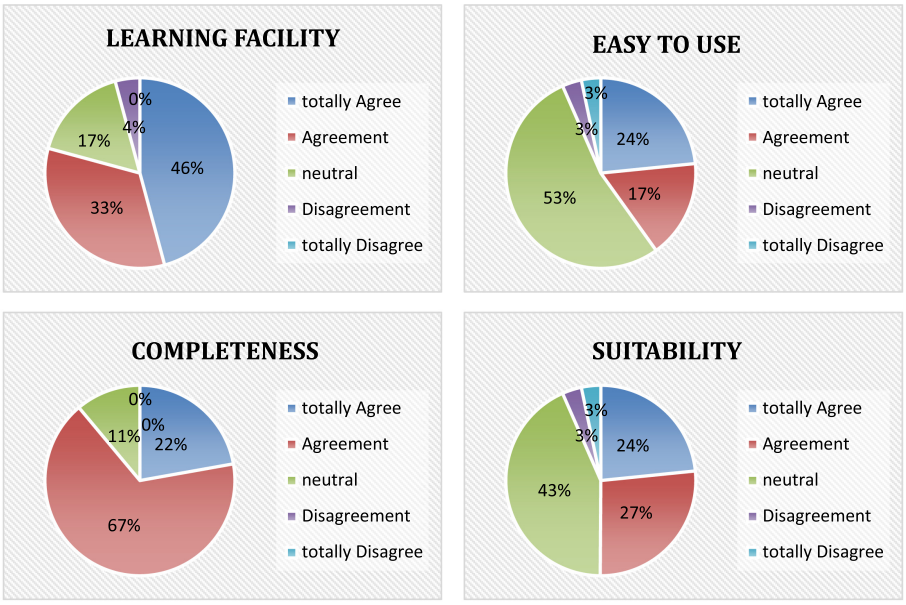


Fig. 1. Expert evaluation results

- To define a flow chart that helps to better understand the process for creating the application with the association of each guideline

Ease of learning:

- The guidelines are written for a non-developer end user, it is necessary to use a more specific and technical language, to make it suitable and easier to use
- The application steps are defined as recommendations, specific steps must be defined, in addition to including numbering, determining whether or not each step is mandatory, and the order in which they should be applied.

4.1 Analysis of the Results

According to the experts' perception, it can be said that the guidelines contain the necessary elements to affirm that they are completeness, given that more than 80% of the respondents agree with this. In addition, it can be said that they are easy of learning, since more than 70% of respondents agree with this because they structurally contain the necessary elements and these are mostly well described.

Nevertheless, since more than 40% of respondent's state that the guidelines do not consider appropriate information, it can be said that they are moderately suitable, this because all the guidelines must be based on the context of the children, mathematics and defined for the design of mobile applications specifically and some are not subject to this, they are very general guidelines that do not differentiate any context. In addition, it can be considered, where according to the experts' perception, 50% of them determine

that the guidelines are not easy to use because they are too extensive, the steps are not clear to apply and the examples presented, in some cases, they do not correspond to the use in the specific context and do not give a guide for its correct application.

These results on suitability and ease of use, according to the analysis carried out, is due to the fact that it is a first version of the guidelines, guidelines that were initially created based on literature review and surveys of teachers in the area, which showed that It was not enough and it was necessary to emphasize more in the context and to generate, in addition to new more specific guidelines for said context, a way to make them easier to use and understand.

4.2 Solutions for Problems Found by Experts

According to the results obtained by the evaluation of experts and their respective analyses, it was possible to determine the following proposed solutions to improve these results and be applied in a later stage of the guidelines, in such a way that they achieve the objective for which they were created.

Easy to use:
To solve a little the difficulty of the correct use of the guidelines since they are extensive, it aims to develop a guide to show the developer an optimal way to use it in the correct order and in the appropriate way, this guide can be handled graphically or in writing.

Suitability:
As most of the guidelines are focused on a more general context, it aims to focus the examples of use to our context (mathematics) and categorize them by parts, since every application needs general guidelines, in this way they are optimized both for our context as for the general context.

Ease of learning:
To solve the deficiencies found in this category, the steps of the application will be listed, written in a better way that shows how to do it by yourself, but not how it could be done, thus showing a step by step, it also will show, what steps are required and which are not.

5 Conclusions and Future Work

This paper presents the first version of a set of usability guidelines for the design of interfaces in interactive mobile applications in the context of learning mathematics in children between 6–7 years old, which were constructed based on guidelines found in the literature review, context analysis, and children's needs.

The validation with experts allowed us to identify elements to improve the content, the structure, the form of presentation, the description of the guidelines, and their semantics. According to the expert opinion, it is determined that the guidelines were complete, easy to learn, moderately easy to use, and moderately suitable. Therefore, it is necessary to define in their description a set of elements that facilitate its use and adapt the existing elements to the specific context to improve its suitability.

From the comments obtained by the experts, it was possible to determine as possible improvements for the following stages of the investigation, the creation of a tool, which

could be considered to have a guide (that determines the step by step of the design of the interfaces in the specific context and for each step which guideline to use) and a flow chart that graphically shows this process, and thus facilitate its use, in addition to the generation of a light version, that is, a new version of the guidelines that only has the identifier, name, category, and description, and apart from having the complement of the guidelines, which contains the application steps and the examples to be used, this in order to access the complement only when necessary and thus not be so extensive for its access.

As future work, the analysis and subsequent application of the suggestions made by the experts should be carried out, in order to generate a more complete version of the guidelines that must subsequently be validated in a real context, initially creating a functional prototype, using the guidelines and in this way, their application will be evaluated in the context for which they were designed, allowing the validation of useful aspects for their definition and subsequent use.

References

1. Marín, V.: La Gamificación educativa. Una alternativa para la enseñanza (2015)
2. Deloitte: Consumo movil en Colombia: Los móviles prueban ser indispensables en un mundo "siempre" conectado, Colombia (2016)
3. Zhang, D., Adipat, B.: Challenges, methodologies, and issues in the usability testing of mobile applications. Int. J. Hum.-Comput. Interact. **18**, 293–308 (2005)
4. Chimarro Chipantiza, V.L., Mazón Olivo, B.E., Cartuche Calva, J.J.: La usabilidad en el desarrollo de software. Machala, UTMACH (2015)
5. Videla Rodriguez, J.J., Sanjuan Perez, A., Martinez Costa, S., Seoane Nolasco, A.: Diseño y usabilidad de interfaces para entornos educativos de realidad aumentada (2017)
6. Collazos, C.A., Arciniegas, J.L., Mondragón, V.M., Garcia Pañeda, X.: Lineamientos de usabilidad para el diseño y evaluacion de la television digital interactiva (2008)
7. Aquino, L.: ¿Quien se come a quien? juego colaborativo para niños de primaria en palms de un ecosistema utilizando bluetooth. Tesis de ingenierar en Computacion (2006)
8. Ocsa, A., Herrera, J., Villalba, K., Suero, G.: Propuesta Para El Diseño Y Desarrollo De Aplicaciones M-Learning: Caso, Apps De Historia Del Perú Como Objetos De Aprendizaje Moviles (2014)
9. Tello Valle, J.A., Yautibug Apugllón, M.E.: implementación de mejores prácticas de usabilidad en el diseño de la interfaz del entorno virtual de aprendizaje de la universidadd de chimborazo, Riobamba (2018)
10. Nataloni, F., Hannover, S., Villanueva, T.G., Lencinas, V.: Investigacion-accion: una oportunidad para generar conocimiento desde la práctica profesional de bibliotecatios y archiveros, Cordoba (2017)
11. N. E. I. 9241-11: Requisitos ergonómicos para trabajos de oficina con pantalla de visualizacion de datos (PDV) ISO 9241-11 (1998)
12. Serzo, H.: Rensis Likert y Douglas Mcgregor. Management Today en español, pp. 33–36, enero de (1984)