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ORIGINAL

Mobile Prototyping As A Gammified Learning Tool

Prototipado Móvil Como Herramienta De Aprendizaje Gammificado

Heidy Elizabeth Vergara-Zurita[1], Ana Lucía Rivera-Abarca[1], Héctor Oswaldo Aguilar-Cajas[1], Jazmín Isabel García-Guerra[1], Miguel Angel Duque-Vaca[1], Jessica Andrea Barreto-Bonilla[2]

[1]Escuela Superior Politécnica de Chimborazo (ESPOCH), Riobamba. Ecuador.
[2]Universidad Estatal de Bolívar. Ecuador.

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Corresponding author: Heidy Elizabeth Vergara-Zurita

ABSTRACT

Introduction: teaching modalities from the pandemic migrate to the digital environment, being an indispensable tool for learning.
Objective: the present study aims to develop the prototyping of a mobile application focused on improving learning in the area of mathematics, using the Design Sprint methodology to determine the characteristics of usability and acceptance by students in the fifth year of the Santo Tomás Apostol de Riobamba Educational Unit (UESTAR).
Method: the research approach is mixed qualitative-quantitative, from the interviews conducted with the teachers of the institution allowed to identify the difficulties of the teaching-learning process related to basic arithmetic operations, the surveys applied to students who used the prototype could be evaluated according to the criteria the level of acceptance and usability of the interface.
Result: in the prototyping process incurs 5 stages according to the Design Sprint methodology understanding, sketch, decision, prototype and validation that contributes to the design of a tangible product of high fidelity ready for evaluation and determine if it meets the parameters of the UX / UI design.
Conclusion: it was concluded that the prototype meets the acceptance of students and teachers based on intuitive navigation, consistency and simplicity, recommending that it be applied as a didactic resource for learning in the area of mathematics.

Keywords: Learning; Digital; Teaching; Gamification; Performance.

RESUMEN

Introducción: las modalidades de enseñanza a partir de la pandemia migran al entorno digital, siendo una herramienta indispensable para el aprendizaje.
Objetivo: el presente estudio tiene como objetivo desarrollar el prototipado de una aplicación móvil enfocado a mejorar el aprendizaje en el área de matemáticas, utilizando la metodología Design Sprint para determinar las características de usabilidad y aceptación por parte de los estudiantes del quinto año de la Unidad Educativa Santo Tomás Apóstol de Riobamba (UESTAR).
Método: el enfoque de la investigación es mixto cuali-cuantitativo, a partir de las entrevistas realizadas a los docentes de la institución permitió identificar las dificultades del proceso enseñanza-aprendizaje relacionados con las operaciones aritméticas básicas, las encuestas aplicadas a los estudiantes que utilizaron el prototipo se pudieron evaluar según los criterios el nivel de aceptación y usabilidad de la interfaz.

Resultado: en el proceso de prototipado incurre 5 etapas según la metodología Design Sprint entendimiento, boceto, decisión, prototipo y validación que contribuye al diseño de un producto tangible de alta fidelidad listo para su evaluación y determinar si cumple con los parámetros del diseño UX / UI.\
Conclusión: se llegó a la conclusión que el prototipo cumple con la aceptación por parte de estudiantes y docentes basados en la navegación intuitive, consistencia y simplicidad, recomendando que sea aplicado como recurso didáctico para el aprendizaje en el área de matemáticas.

Palabras clave: Aprendizaje; Digital; Enseñanza; Gamificación; Rendimiento.

INTRODUCTION

Mobile applications since the pandemic and the migration of education to digital environments have significantly increased the use of technological tools for the teaching-learning process of children, with a 61 % increase in the use of mobile applications in Latin America and particularly in Ecuador, where it reached 29,1 %. According to the study Impact of mobile devices on education (Impact of mobile devices on education), this country uses them as a learning tool.[1]

Education during the pandemic has been forced to move to virtual platforms such as Google Classroom, Microsoft Teams, virtual classrooms, and Zoom.[2] To continue the teaching-learning process, teachers have changed their teaching methods, using technological tools to adapt to this change in teaching methodologies. This has created a need for mobile applications that help students improve their skills and abilities in different areas of knowledge.[3]

The prototyping stage considers design principles, such as defining the elements that will form part of the graphic line, including color, typography, shapes, grid, etc. In turn, each of these elements helps to make the composition attractive, dynamic, and functional, complying with the laws of Gestalt or the principles of visual logic,[4] which are adapted so that the elements relate to the application environment.[5]

The concept of UCD has appeared constantly in the context of usable product development; however, no standard defines a single UCD methodology, and different models can be found.[6] Generally, they are all oriented toward the product's users, who must participate throughout the process. It is also iterative and multidisciplinary, and its objective is to obtain usable products that are satisfactory for users.[7]

The concept of interaction design is linked to Information Architecture, "it refers to the activity and result of defining the interactive behavior of the application prototype; that is, establishing what actions will be offered to the user at each moment, and how the app will respond to the actions performed.[8] On the other hand, interaction is a two-way communication resource between two parties: person to person, person to object, or object to object; it refers to the fact of action and reaction; the action is achieved when one party sends a signal to another, and the reaction is the response obtained from the other party.[9]

The principles of interface design arise from the requirements of human-machine interaction. The golden rules of interface design relate to the functionality of a product and are not expressed in the process; these rules give control to the user to reduce cognitive load and build a consistent interface. Among interface design principles are familiarity, minimal surprise, uniformity, recoverability, user guidance, user diversity, mental model, and formal model.[10]

Each interface will have a different style depending on the operating system for which it is designed; "the interface of an application prototype is like the clothes you wear to go out. It is also the layer between the user and the functional heart of the app, the place where interactions are born. The designer's job is to understand the personality of each operating system to develop applications that are visually consistent with the platform they are intended for. In addition, a key element will always be to create a strong visual identity to differentiate it from others and focus on usability.[11]

Intuitive navigation is linked to consistency. Similarly, when developing an interface, the way users navigate between content requires greater attention to make it easy to understand and avoid confusing navigation that disorients people.[12] It is also essential for users to know and anticipate what will happen after pressing a button or how the screens will be displayed, as this is a great relief for the user because it saves them unnecessary effort. Intuitive navigation translates into smooth and effortless use of the interface.

When designing interaction, heuristic principles should be taken into account to enable usability testing on websites, mobile applications, software, or digital products, including visibility of system status, the relationship between the system and the real world, user control and freedom, consistency and standards, error prevention, recognition before recall, flexibility and time of use, aesthetics and minimalist design, helping users recognize, diagnose and recover from errors, and help and documentation.[13]

A mobile application is to a mobile phone what a program is to a computer; an application "is a piece of software that runs on mobile phones and tablets. To begin with, native applications are designed and programmed specifically for each operating system[14] and are usually found in the stores of each operating

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system. Next are web applications, which can be accessed from a browser regardless of the platform or operating system. 3) Finally, hybrid applications are available from the browser and in the application store.[14]

Hybrid applications combine native and web applications; however, unlike web applications,[15] hybrid applications allow access to the capabilities of the mobile device using libraries, just as a native application would. Similarly, these types of applications use a visual system that is not governed by the operating system's guidelines; however, it is essential to use the native controls and buttons of each platform to approximate the aesthetics of each one.

Mathematics is often the most difficult subject for many students to understand, which is why any materials that can be made available to them are welcome. They often use their mobile phones or tablets, so apps are a possible resource. Educational apps bring about a paradigm shift in educational methodologies, moving away from passive methods, where the teacher is the protagonist, to active learning, where students are at the center, giving them autonomy and the ability to learn by doing.[16,17,18]

Mobile learning or M-Learning is considered an extension of e-learning, taking place virtually and bringing with it different modern methods that complement learning through the use of mobile devices, such as mobile phones, laptops, tablets, and any device with wireless internet access that allows young people to learn interactively and explore digital resources and tools. M-learning, therefore, offers a wide range of possibilities. The most significant advantage of mobile learning is the ability to access educational content anywhere and anytime with a mobile device.[19,20]

Learning is a cognitive process in the brain through which knowledge and skills acquired by individuals throughout their lives and experiences are acquired, stored, and used. Learning also includes perceptions, thinking, memory, and language that produce permanent changes in behavior. The purpose of the teaching and learning process is to contribute to the comprehensive development of the personality of future professionals. It is a process of communication and socialization in which the teacher is the primary communicator responsible for presenting, organizing, and facilitating the different content to the students. At the same time, they communicate with the teacher, each other, and the rest of the community.[21]

The teaching and learning process in mathematics is the challenge that both students and teachers face in the academic field. To achieve an optimal learning and teaching process in this area, it is necessary to use technological tools that allow for a multidirectional connection between the teacher, the student, and the information within the network. Similarly, it is essential to make students feel supported in their learning process despite using a digital device.[22]

Education must advance hand in hand with both technology and society. This is where mobile learning takes center stage due to its various advantages, such as its flexibility in accessing information. The range of opportunities to explore with this learning methodology is wide, starting with the ubiquity and autonomy fundamental to mobile learning because all that is needed is a device with wireless connectivity to access all the information. Therefore, this research aimed to design and validate a mobile prototype as a gamified learning tool to improve learning in mathematics.

METHOD

In designing the prototype of an application for Android devices that serves as a support tool for learning basic arithmetic operations, aimed at fifth-year students at the Santo Tomás Apóstol Educational Unit in Riobamba, it takes a qualitative-quantitative approach to collect primary qualitative information through interviews with fifth-year primary school teachers at UESTAR and through surveys administered to students who use the prototype to evaluate its usability in a quantifiable manner. Deductive and inductive methods were used to collect and analyze the information gathered from UESTAR to continue with the subsequent phases of the Design Sprint, establish the parameters and starting point for the creation of the prototype proposal, and determine whether it complies with the usability principles established by Nielsen (1994). With the synthetic method, the information is fragmented for analysis and implementation in the first stage of the prototype, using the experimental procedure for prototype usability testing.

The Design Sprint methodology was used to develop the prototype, graphically showing its basic functionalities and answering essential questions to save time and resources in its creation. The stages include the first stage, Preparation, where information is collected on the subject of study and the learning topics in mathematics. The second stage, Understanding, begins with interviews with fifth-year primary school teachers at the Santo Tomás Apóstol Riobamba Educational Unit to synthesize the information and set long-term goals. A voting session is held among three to four people with three votes to indicate the options they consider appropriate for the project, resulting in three goals that help establish the Sprint questions. Among the results obtained to meet the proposed objectives, a user experience map is created, describing how students and teachers will achieve these goals through the evaluation of the prototype.

In the third stage, rapid demos were carried out for ideation, where notes were taken, and sketches were made. In Crazy 8's, one or two options are selected to complete the eight process variations. In the final solution, one or two screens of the interface are drawn to get a clear idea of this stage. The fourth stage, Decision, is before the prototype, where the storyboard is created as the user flow. The user flow is a sequence of screens that students must follow during the prototype validation, detailing the low-quality wireframes.

In the fifth stage, Prototype, medium-fidelity wireframes were created along with a style guide establishing graphic elements such as the logo, colour scheme, buttons, icons, and fonts. This is followed by the high-fidelity interface design, using the graphic elements from the style guide (the screens to be prototyped and designed are considered in the decision phase). In the final validation stage, the prototype created in the previous stage was tested with fifth-year primary school students at the Santo Tomás Apóstol Riobamba Educational Unit. A survey was then conducted to evaluate the usability of the prototype.

Study population and sample

The study population consisted of 160 fifth-year primary school students from the Santo Tomás Apóstol Riobamba Educational Unit, divided into four parallel groups of 40 students each. The sample was selected according to the guidelines set out by Tom Tullis and Larry Wood.(23) Five students from each parallel class were chosen to use the prototype and complete the survey to evaluate its usability for 20 students, 10 girls, and 10 boys.

Four teachers from the Educational Unit were interviewed to identify the difficulties they face in the teaching-learning process of mathematics and to consider this information when designing the prototype. table 1 presents the results obtained.

Table 1. Interviews with fifth-year primary school teachers

Interviewee	Parallel	Summary
Teacher 1	A	She mentions the importance of making teaching interactive for children, and also highlights that not all children learn in the same way or at the same time, which leads her to seek new alternatives for teaching her students.
Teacher 2	B	He says that the most difficult challenge he faces is making children understand that mathematics is exact, and that attitudes and aptitudes differ, which means that learning is linked to these factors, so each child learns at their own pace.
Teacher 3	C	She highlights the importance of using playful strategies for teaching basic operations to children. She believes that with the right methodology, teaching can be optimised. It is also worth noting that she believes it is important to learn through play, because what is learned through play is difficult to forget and easy to learn.
Teacher 4	D	He says that one of the challenges of teaching is that parents do not complement learning at home and are not committed to their children's education. He also considers it extremely important for children to learn through play.

Planning and design of mobile prototyping as a gamified learning tool for mathematics learning.

Goal setting

To set short—and long-term goals, three 5-minute sessions are planned, and the question 'Where do we want to be in six months, a year, or even five years from now?' is asked. Afterwards, a voting session is organized to select the three goals that define the Sprint.

Sprint challenges

To select the goals, the following questions are answered: How could this fail? And what could prevent us from achieving the goals? This is done in two 5-minute sessions based on the three goals selected in the voting session. The challenges involved in this Design Sprint session were then determined, and the Sprint challenges were reframed as opportunities. In later stages, two 5-minute sessions are held for this technique, in which a voting session is held with five users, who have five opportunities to place the results on the user experience map.

User experience map

The user experience map shows children's journey during the user test. Under each step, a challenge or opportunity was placed to ensure that the interface and prototype were developed correctly.

Quick demos

To create the sketch, we searched for different solutions that could be used to make the prototype. Design Sprint is an agile methodology, so we needed to hold sessions lasting no longer than 40 minutes. Hence, during a 30-minute session, we conducted brief research into similar applications, interfaces, and other niches. Although the interfaces share identical elements in terms of design and composition, having several references allowed us to design an interface with its essence and identity. In addition, the learning curve with the children during the usability test was reduced, and these demos served as a starting point for developing the next steps in the second phase of the Design Sprint.

Take notes

This was done in a 10-minute session in which concepts that help with the graphic design of the interface were written down.

Sketching and Crazy 8's

Once the quick notes were taken, the next step was to start drawing. This was done in a 10-minute session during which it was important to stay focused on the essentials and capture ideas, elements, and the interface design layout. Then, based on the quick notes and sketches, an 8-minute session was held, which consisted of creating an idea in one minute.

Final solution

This step required a 20-minute session during which two interface screens were quickly drawn. It was essential that the idea be self-explanatory and that any elements that needed reinforcement be supplemented with post-it notes.

Decision

Storyboard

Once the user flow was defined, a storyboard was created to help the audience understand the prototype's features and functionality. It also illustrates how children are expected to interact with it.

Low-quality wireframes

During this part, we outlined how the different screens were expected to be displayed and, based on the user flow, the interaction between them. We also determined which elements would be included in the interface.

Prototype

During the phase before completing the Sprint, various activities were carried out that enabled the creation of the prototype. First, the style guide, which includes the logo, color scheme, typography, icons, and buttons, was defined.

Style guide

The style guide includes various elements that enabled the prototype's graphical interface construction. The Isologo denoted the essence of basic arithmetic operations, which, together with the color scheme, represented each operation with a color: red for addition, green for subtraction, purple for multiplication, and yellow for division. This guide also included the interface icons and the typography's use and styles.

The button design was kept simple and limited to each option available within the prototype. The color of each button varied depending on the option selected by the user. In this case, red was chosen as the default color for students, while purple was used for teachers. Similarly, within the interface, the color scheme varied according to the option selected by the user.

Active buttons were displayed for the operations available during the user test. These were gradually activated as the children completed the tasks. The deactivated buttons, which were activated as users completed the previous levels, restricted children from accessing options to which they did not yet have access.

Once the style guide was created and the elements were defined, we designed the user interface and finalized the prototyping. The prototype contains different options for learning basic arithmetic operations based on the requirements of fifth-year primary school children.

Home screen

The home screen includes a splash screen with an animation showing the app's and ESPOCH's logo, followed by the onboarding screen, which provides general information about the available options.

Score screen (teachers)

The teacher score screens showed a dashboard with information on the student's scores, the teacher's name, and the class they belong to.

Class and profile selection screens

These included the four fifth-year classes. After selecting the corresponding class, the screen with the children's profiles was displayed.

Main screen

This screen showed general user information, such as their name, score, and current level. The main screen also presented the different options available to the children. This screen contained the user configuration options, where only profile changes were enabled. Finally, there was a score screen that displayed a dashboard with the scores of all students.

Game screens

Finally, the game screens, including the map design and levels, were created. Once inside the game, the user had two options: finish the level and continue to the next one, or, if they made a mistake, a pop-up screen appeared that encouraged the children to keep trying until they selected the correct answer.

Validation

During the last stage of the Design Sprint, we went to the Santo Tomás Apóstol Riobamba Educational Unit, where, thanks to the institution's support, we carried out the usability test. The validation was carried out in two groups of 10 students previously selected by fifth-year primary school teachers. According to Tom Tullis and Larry Wood, with a sample of 20 users, it is possible to identify 95 % of usability problems in an interface.(24) Once the test was applied to the children, they completed a survey (table 2) that evaluated the prototype's ease of use and their reactions to it. The questions are described below

Table 2. Questions for validating mobile prototyping as a gamified learning tool

Question	Statement
1	Do you think it is necessary to use an app to learn how to add, subtract, multiply and divide in the classroom?
2	Was it easy for you to find your parallel within this screen?
3	On the next screen, how easy was it for you to find the profile you were directed to?
4	Do you consider the following colours attractive?
5	In the following images, rate from 1 to 5 how easy you found it to read the content.
6	Do you consider that the following images represent your description?
7	Do you think the following graphs represent the action described?
8	After using the app, how easy was it for you to complete the assigned tasks?
9	Next, you were shown different images of the application. Please rate each one on a scale of 1 to 5 depending on how attractive you found it.
10	Select the loading time of the application you use for prototyping.

RESULTS

Regarding whether students believe it is necessary to use an app to learn addition, subtraction, multiplication, and division in the classroom, 90 % of respondents considered a mobile app required for teaching basic arithmetic operations (Item 1), while regarding the ease of finding their parallel on the screen (Item 2), 90 % of students indicated that it was easy to see their parallel on the selection screen. However, it is worth mentioning that there was some confusion about how to interact with the app; although the expected gesture was to drag, the children tapped, the results of which can be seen in figure 1.

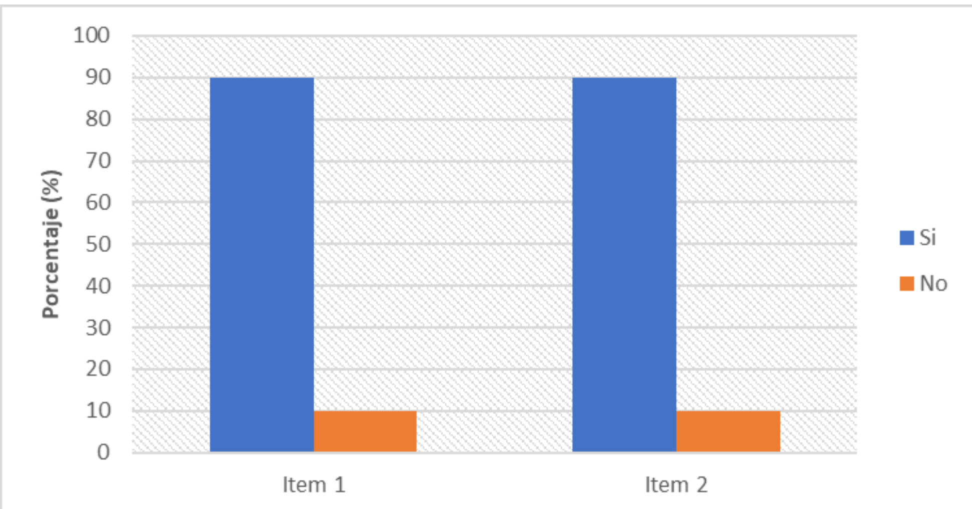

Figure 1. Validation results for items 1 and 2 for the validation of mobile prototyping as a gamified learning tool

On the other hand, regarding how easy it was to find the profile (item 3), 95 % of students considered it easy, while 5 % found it challenging. Therefore, we asked whether the colors used were attractive (item 4), to which 95 % responded that the colors selected for the interface design were beautiful. In comparison, only 5 % did not, as shown in figure 2.

Figure 2. Validation results for items 3 and 4 for the validation of mobile prototyping as a gamified learning tool

When rating how easy it was to read the content (Item 5), 100 % considered it very easy to read on the prototype's main screen. They were then asked if they thought the following images represented their description (Item 6), to which 100 % of respondents mentioned that the cards on the main screen represented the designated operations. They were also asked whether the graphics represented the action described (Item 7), to which 100 % of respondents considered that the icons represented the action they expected when pressing, the results of which are shown in figure 3.

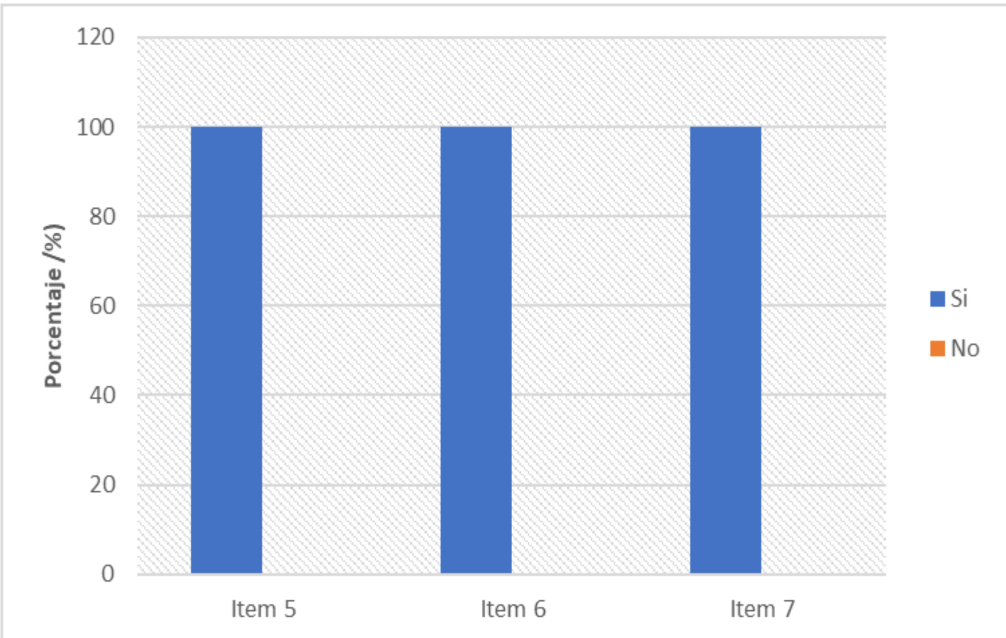

Figure 3. Validation results for items 5, 6, and 7 for the validation of mobile prototyping as a gamified learning tool

Finally, after using the application, users were asked to rate how easy it was for them to complete the assigned tasks (Item 8). Ninety-five percent found the user test easy to complete, while 5 % found the tasks challenging. This opinion was confirmed when comparing different images of the application used on the main screen (Item 9). Notably, 90 % found the design very attractive, and only 10 % found it beautiful, as shown in figure 4.

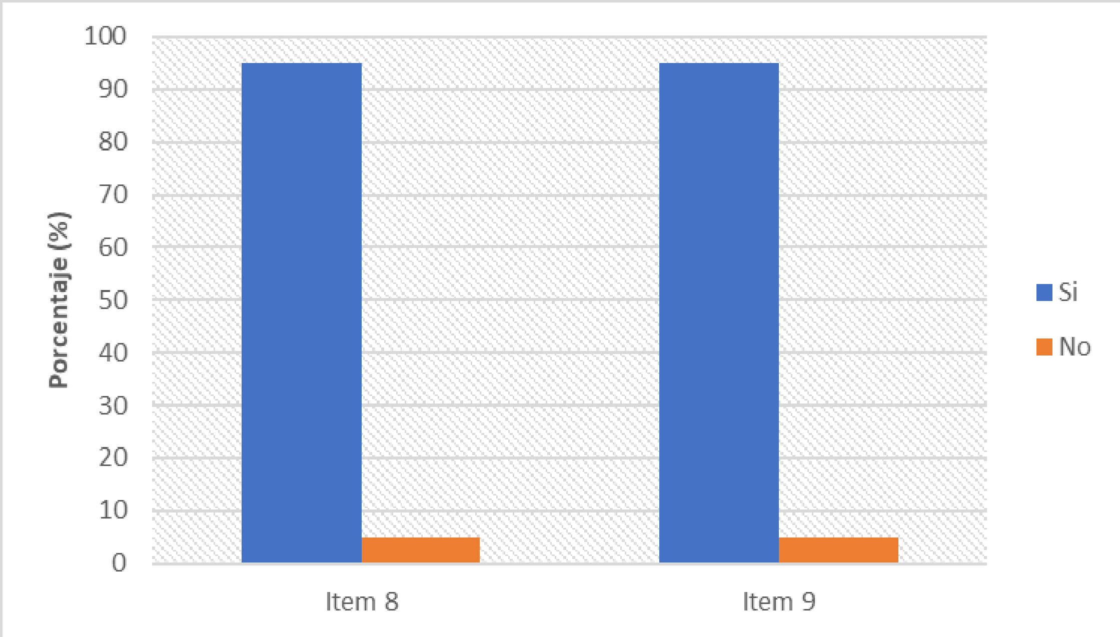

Figure 4. Validation results for items 8 and 9 for the validation of mobile prototyping as a gamified learning tool

Finally, the application loading time was evaluated (Item 10), where respondents rated the application loading time differently; 80 % reported loading times of 1 to 3 seconds, 10 % reported 3 to 6 seconds, and the remaining 10 % reported more than 6 seconds; this was due to the internet bandwidth at the time of the user test, The results are presented in table 3.

Table 3. Validation results for item 10 for the validation of mobile prototyping as a gamified learning tool

Options	Answers
1 to 3 seconds	16
3 to 6 seconds	2
More than 6 seconds	2
Total	20

DISCUSSION

In general, fifth-year primary school students received the prototype very well. They found the proposal of learning to add, subtract, multiply, and divide through the application appropriate. They were attracted to the product by its micro-interactions, the dynamics of learning through play, and its visual simplicity. Both the color scheme and the elements were appropriate, and the predominance of white conveyed cleanliness and simplicity, with results similar to other apps used in mathematics learning.[25,26]

On the other hand, the prototype did not achieve proper interaction within some screens. Interacting with the parallel selection screen was confusing, as the component within it was designed for swiping interaction, and users tapped, which ultimately resulted in them not selecting the correct course. Although they had no problems solving the exercises, the children were curious to know how to continue playing, which is one of the advantages of this type of device in terms of motivation.[27,28]

The concept shows promise. Due to its limited success, usability tests were applied as observed in previous experiences.[29,30] The result is an approximation of how the prototype would interact with the real world. Once users complete the tasks assigned by the moderator, it is concluded that the prototype is very well accepted and functional based on the test results.

However, it is recommended that the prototype be iterated, incorporating up to level 10 of the mathematics area to determine whether the proposal is viable for development. The prototype should be evaluated with 20 new users to obtain further information. Based on the latest data obtained, we would move on to the construction of a minimum viable product or carry out new iterations, given that user validation is key to the acceptance of the prototype, similar to the evaluation carried out by Yadav & Chakraborty to determine the negative and positive aspects of the device.

User experience is a key approach to determining whether the experience within an application prototype has been good or bad, including design and usability. In this sense, visual simplicity is directly related to usability. Being simple implies, to a certain extent, being minimal and having few elements, but above all, those present in the interface have a well-defined function. According to the principle of consistency, systems are easier to use and learn when similar parts are expressed in similar ways. Consistency allows knowledge to be transferred effectively to new contexts, learn more quickly, and focus attention on the relevant aspects of a task.[31]

Usability is associated with the ease with which a digital system or product can be used by users, making it easy to perform tasks comfortably, quickly, and effectively.[32] Usability is an attribute of quality, and the components or variables used to evaluate it are effectiveness, efficiency, and satisfaction; however, Nielsen proposes two more: 1) ease of learning, which refers to how easy it is for users to perform basic tasks the first time they use an interactive product; 2) memorability, which is measured when a user returns to the design after a period of not using it.

CONCLUSIONS

Once the central focus of the prototype was defined through the early stages of the Design Sprint, it was concluded that the problem to be evaluated was children's lack of interest in learning basic arithmetic operations. This allows for the design of an intuitive and easy-to-learn interface that is evaluated with a user test, with motivation for learning mathematics being the most notable advantage of mobile prototyping as a gamified learning tool.

Based on the experience and opinions of fifth-year primary school teachers, the difficulties they face during the teaching and learning process in mathematics were identified qualitatively. The objectives of the Design Sprint are determined through quantifiable information, which is why several voting sessions were held to allow the prototype to continue to be developed.

The high-fidelity interface design allows for usability testing with UESTAR students. During the prototyping phase, it is essential to establish the interface style guide that will guide the interface design. Design Sprint is an agile methodology that helps evaluate product acceptance in five stages, demonstrating a positive assessment of mobile prototyping as a gamified learning tool.

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AUTHOR CONTRIBUTION
Conceptualization: Jazmín Isabel García-Guerra.
Data curation: Jazmín Isabel García-Guerra.
Formal analysis: Héctor Aguilar-Cajas.
Research: Héctor Aguilar-Cajas.
Methodology: Héctor Aguilar-Cajas.
Project management: Héctor Aguilar-Cajas.
Resources: Ana Lucía Rivera-Abarca.
Software: Ana Lucía Rivera-Abarca.
Supervision: Ana Lucía Rivera-Abarca.
Validation: Jazmín Isabel García-Guerra.
Visualization: Jazmín Isabel García-Guerra.