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Video games as a support for strengthening arithmetic skills in primary school students: A description of their development

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Abstract

This study aims to describe the design, development, and evaluation process of three serious educational video games intended to strengthen arithmetic skills among fourth-, fifth-, and sixth-grade elementary school students. The project was developed within the framework of the New Mexican School educational model and aligned with the mathematics learning objectives established by the Mexican Ministry of Public Education (SEP), with the goal of providing curriculum-based digital resources that promote meaningful and motivating learning experiences. A design-based research approach was adopted, following a structured methodology for the development of serious educational games. The process comprised four sequential phases: initiation, design, production, and testing. During the evaluation stage, the games were implemented with 150 students enrolled in a public elementary school. Usability, functionality, perceived usefulness, and student engagement were assessed using an eight-item Likert-scale questionnaire designed to measure students' perceptions of their learning experience and interaction with the games. The findings revealed a high level of acceptance and a positive user experience. Overall, 89% of participants considered the games useful for reinforcing mental calculation skills, 78% reported successfully practicing fraction operations and equivalent fractions, and 92% indicated that the challenges maintained their interest and motivation throughout the activities. These results suggest that the proposed games effectively support arithmetic practice while fostering active participation and sustained engagement.

Keywords: Arithmetic skills, Educational video games, Gamification, Mathematics learning, Primary education, Serious games.

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Contents

Contribution of this paper to the literature
This study contributes to the literature by presenting a curriculum-aligned, design-based development of three serious games for primary mathematics and validating their usability in a real school context. It integrates pedagogical objectives, constructivist principles, and technical development, offering practical evidence for technology-enhanced arithmetic learning.

1. Introduction

Personalized education has been crucial throughout history, allowing students to approach content at their own pace and learning rhythm (Von-Feigenblatt, Peña-Acuña, & Cardoso-Pulido, 2023), thus fostering the development of their skills and abilities (Luna-Gijón, Nava-Cuahutle, & Martínez-Cantero, 2022). In recent years, teachers have needed to leverage technology to meet student demands, particularly during and after the COVID-19 lockdowns, as classes were held online (Ministry of Public Education, 2020). Upon returning to in-person classes, teachers have had to help students catch up, and one strategy employed has been personalized education through smaller class sizes (Pérez & Ahedo, 2020). However, one challenge they have faced is insufficient time to cover both the curriculum for the student's current grade level and address any learning gaps from previous grades. Furthermore, the time children spend at school is often insufficient to allow them to catch up in subjects where they are behind (Riudavets-Barcons & Uusitalo, 2024; Sabarwal, Chang, Angrist, & D'Souza, 2023).

Given the scenario presented in the preceding paragraphs, the problem this paper addresses is that primary school teachers need tools to support their classroom work so that their students can develop essential mathematical skills, such as problem-solving and decision-making. Therefore, to support primary school students in reinforcing their math knowledge in a way that aligns with their grade level, a tool consisting of three video games was developed. This tool allows students in grades 4th, 5th, and 6th to practice basic arithmetic operations: addition, subtraction, multiplication, and division of whole numbers; finding equivalent fractions; and performing operations with fractions. This was precisely the objective of the research project developed, the information from which is presented in this paper.

Having an institutional framework is essential, so the Curriculum and Study Program for Primary Education from the Mexican Ministry of Education (Ministry of Public Education, 2017) was consulted, and the SEP's 4th, 5th, and 6th grade mathematics textbooks were reviewed (Ministry of Public Education, 2019). These books were chosen because they contain defined lessons for each arithmetic topic. Subsequently, a primary school was contacted, and ongoing communication was maintained with its staff throughout the application development process.

The institution contacted is the *Cándido Navarro* Primary School, which has been working with the Interactive Groups technique. This technique involves planning one activity per week, establishing the objectives to be achieved, the skills to be developed, and the problems to be solved. This planning is called the Learning Development Process (LDP). To implement it, four teams of five children each are formed. Each team is assigned a problem to solve within a set time, and at the end of that time, they are assigned a second problem. Using the same dynamic, they must complete the resolution of four problems. While the children are solving the problems, the teachers observe and note any questions they may have and how they overcame each challenge. At the end, feedback is given to clarify the areas where they had difficulties.

According to Ibrokhimovich and Mirzaxolmatovna (2022), mathematics plays a fundamental role in early childhood education, as it is a key support for children's cognitive development and also because it develops critical-thinking and decision-making skills in them (Rodriguez-Jimenez, de la Cruz-Campos, Campos-Soto, & Ramos-Navas-Parejo, 2023). The OECD supports the need to integrate adaptive digital technologies into primary education. In Mexico, mathematics in primary education is organized into three thematic areas in accordance with the SEP program.

1. "Number, Algebra, and Variation
- Number
- Addition and Subtraction
- Multiplication and Division
- Proportionality
- Equations
- Functions
- Patterns, Geometric Figures, and Equivalent Expressions

2. Shape, Space, and Measurement
- Spatial Location
- Geometric Figures and Solids
- Magnitudes and Measurements

3. Data Analysis
- Statistics
- Probability"

For the development of the three video games, we worked with content from the thematic area "Numbers, Algebra, and Variation," as this is the basis for addressing the other two thematic areas.

The situation teachers face when teaching this subject presents several challenges, including its abstract nature and the need to maintain children's attention for extended periods, among others. Therefore, specialized applications or software are required to allow children to interact with the content dynamically and aid in understanding concepts (Sobota & Pietriková, 2023).

The abstract nature of mathematics and the need to motivate students to take an interest in learning it have led teachers to seek alternative teaching strategies that incorporate technology, such as specialized applications or software that allow children to interact with content dynamically and help them understand concepts (Sobota & Pietriková, 2023).

Rodriguez-Jimenez et al. (2023) point out that the use of software helps children strengthen their arithmetic skills, as well as increase their motivation and interest in participating in activities. Authors such as Engelbrecht and Borba (2024) comment that educational mathematics software allows for the understanding of abstract concepts due to the use of visual resources and interaction with them.

Studies such as those presented by Attard (2015) and Chauhan (2017) indicate that adaptive applications, due to the algorithms they employ, are effective in improving students' academic performance by tailoring content to students' cognitive levels.

According to Piaget's constructivist theory (Piaget, 1969), assimilation and accommodation are fundamental to the construction of knowledge. Saldarriaga-Zambrano, Bravo-Cedeño, and Loor-Rivadeneira (2016) point out that educational mathematics software represents an environment that facilitates these processes through the child's active interaction with the activities. Furthermore, when applications allow for repetitive practice and provide feedback to the student, they strengthen their cognitive structures (Mayer, 2019).

1.1. Applications that Employ Educational Video Games

The use of video games for educational purposes has increased significantly in recent years, especially in contexts where students need to reinforce skills and maintain motivation through interactive activities. These resources, commonly called serious games, combine playful elements with clearly defined educational objectives, enabling learning through experimentation, problem-solving, and immediate feedback Del-Moral-Pérez, Guzmán-Duque, and Fernández (2014).

From a technical standpoint, most current video games are developed using graphics engines that integrate animations, sounds, physics, and interactive interfaces into a single environment. The use of graphics engines allows curricular content to be transformed into hands-on experiences, enabling children to interact with numerical representations, visualize equivalencies, or solve problems through direct actions within the digital environment (Barczak & Woźniak, 2020; Bourgonjon, Valcke, Soetaert, & Schellens, 2010). This type of interaction fosters assimilation and accommodation processes, as proposed by Piaget's constructivist theory, since the student constructs knowledge through action and reflection on that action (Saldarriaga-Zambrano et al., 2016).

Based on these contributions, this project adopts educational video games as a tool to strengthen arithmetic skills among 4th-, 5th-, and 6th-grade students. Evidence from previous research guided the design of three video games that integrate playful and educational challenges aligned with the Ministry of Public Education (2017) curriculum and address the needs identified at the Cándido Navarro Elementary School.

This represents a great advantage when developing video games, since you have total control of the project, having to learn to use only one program, and, even more importantly, it gives you the possibility of developing other video games using the same engine, regardless of whether they have a completely different story or graphics; it can even be used to program games of different genres or dimensions (2D or 3D), although this will depend more on the capabilities of the video game engine (Trasobares, Domingo, Casamayor, Blasco, & Cetina, 2025).

1.2. Research Objective and Research Questions

The general objective of this study was to design, develop, and evaluate three curriculum-aligned educational video games aimed at strengthening arithmetic skills in 4th-, 5th-, and 6th-grade primary school students.

To guide the research process, the following research question was formulated:

How do students respond in terms of engagement and perceived reinforcement of arithmetic skills when interacting with the developed games?

2. Methods and Materials

This study followed a design-based research approach focused on the structured development and real-context validation of educational serious games (Hernández & Mendoza, 2023). Rather than implementing a controlled experimental intervention, the research aimed to design, refine, and evaluate the usability and pedagogical alignment of three video games intended to reinforce arithmetic skills in primary education.

Due to the nature of the project, a methodology specifically created for Educational Serious Games was selected, following the proposal by De Lope and Medina-Medina (2017). This approach is largely grounded in Scrum principles, adopting an iterative and incremental development process, and is structured into four main phases: (1) Initiation, (2) Design, (3) Production, and (4) Testing. In this regard, Tokac, Novak, and Thompson (2019) demonstrate the positive impact of serious games in mathematics in basic education.

2.1. Initiation Phase

In this phase, the educational objectives and competencies supporting the application's development were defined.

Table 1 presents a description of each objective, obtained from the study plans and programs provided by the Ministry of Public Education (2017). As shown in Table 1, each game has an identifier and a name that were used in subsequent development phases.

Table 1. Specification of Educational Objectives.

Identifier	Description
OE1	Developmental calculation skills, both exact and approximate, for different tasks, depending on the student's grade level. These tasks may include addition, subtraction, multiplication, division, and comparison of numbers (greater than or less than).
OE2	Learn and reinforce methods for adding and subtracting fractions according to the complexity appropriate to the student's current grade level.
OE3	Learn and reinforce the method for multiplying natural numbers according to the complexity appropriate to the student's current grade level.
OE4	Understand and reinforce ratios between two natural numbers that represent proportionality in different problems.
OE5	Understand and calculate missing values in proportionality problems using natural numbers.

Once the objectives were identified, the educational competencies were established, which are found in Table 2.

Table 2. Educational Competencies.

Identifier	Description
CE1	Ability to solve addition and subtraction operations with natural numbers, as well as compare quantities using the symbols <, >, or =.
CE2	Understanding fraction equivalence to perform basic operations with fractions, useful for academic learning and daily life.
CE3	Ability to solve multiplication and division operations with natural numbers of different digit lengths in daily life.
CE4	Ability to identify and solve proportionality problems in daily life.

Based on the objectives and competencies defined in meetings with teachers and students at the Cándido Navarro School, it was decided that there would be three video games: The first, called *Carreritas* (Little Races), focuses on reinforcing basic operations with natural numbers and comparing them using the symbols >, <, and =. The second video game, called *Chocolatoso* (Chocolatey), helps children find equivalent fractions so they can add and subtract fractions with different denominators. The third video game, called *Espíritus chocarreros* (Mischievous Spirits), allows children to practice multiplication and division with natural numbers. Matiliztli is the name of the application that contains the three video games.

In this initial phase, the characteristics of the three video games were also defined (Hamari et al., 2016), which are:

- Hardware Architecture: All video games will be available exclusively for mobile devices running Android 8.0 or later. Devices must have an internet connection to obtain and send user information and scores, either via Wi-Fi or mobile data. The device must also support touch, although most, if not all, devices already have this functionality built in by default.
- Target Audience Engagement: The games are aimed at casual gamers, with an average session duration of around 30 minutes. The primary users are students in grades 4 through 6 who have at least a basic level of familiarity with mobile devices.
- Deployment: Available online via the Play Store for Android mobile devices.
- Difficulty: The complexity of the proposed serious games is defined by the grade level of the elementary school students. Therefore, depending on whether the student is in fourth, fifth, or sixth grade, the complexity of the educational challenges to be solved, as well as the type of educational challenge, will vary.

2.2. Design Phase

In this phase, the stories, scenarios, scenes, characters, and challenges of each video game were designed. The elements designed for each video game are presented below.

2.2.1. Video Game Stories, Character and Setting Sketches

In this stage, the narrative elements and visual components of each video game were designed to provide meaningful context for the learning activities. The stories were developed considering the educational objectives of the project, integrating playful elements that encourage students' curiosity and participation while solving arithmetic challenges.

The characters were created as guides and interactive elements within the games, helping to establish a connection between the players and the learning environment. Likewise, the settings and scenarios were designed through preliminary sketches that defined the visual style, environments, and objects involved in each activity. These sketches served as references for the subsequent development of the video games, ensuring coherence among the narrative, graphical elements, and mathematical challenges presented to elementary school students.

2.2.1.1. Video Game: Little Races

Cecilia is a sixth-grader who is going to run a race to reach the finals and compete against other schools. But this race is special because she must answer arithmetic problems that appear along the way. She must get the highest score, so she needs your help to answer correctly. The physical education teacher, Pepe, is training the competitors. Figure 1 shows a sketch of Cecilia, and Figure 2 shows a sketch of Professor Pepe.

The track has three lanes, and above each one, fruits will appear with the possible answers to the question at the top (arithmetic operations of addition, subtraction, multiplication, or division of whole and decimal numbers, as well as the symbols greater than, less than, or equal to, so that one of the three can be selected when comparing quantities).

Cecilia starts in the middle lane. You can move the character to a different lane by swiping left or right on the screen.

The goal of the game is to move to the lane containing the correct answer so Cecilia can grab the fruit. The character can only move left or right, not forward or backward; however, the answers or fruits will move downward, giving the illusion that Cecilia is running toward them.

The more correct answers, the higher the score. Figure 1 shows the two characters from the Little Races video game (Cecilia and Roberto, the teacher), which is the first screen students see when they start the game. Figure 2 shows the second screen of the game.

Figure 1. Screen from the video game Little Races with the two characters (Cecilia and Maestro Roberto).

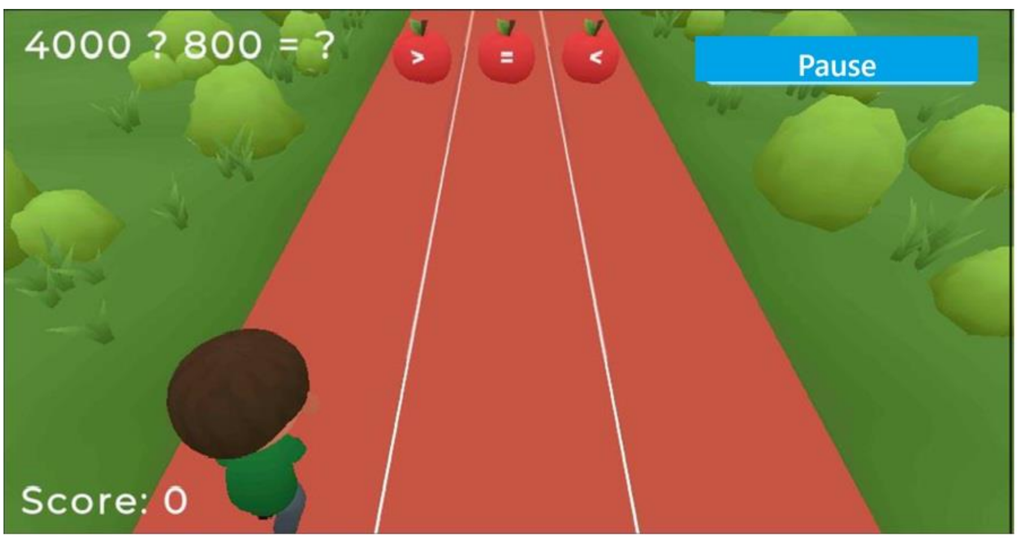

Figure 2. Screenshot of the Little Races video game showing the three-lane track scenario.

If Cecilia achieves an excellent score, an animation will appear indicating that she won first place and that she will be selected to compete against other schools.

If Cecilia does not win, an animation will appear with a message encouraging her not to be discouraged and to keep trying.

2.2.1.2. Chocolatey Video Game

Roberto helps his parents make chocolate desserts after school. At the beginning, Roberto explains the situation and thanks them for their help. Figure 3 shows the first screen of the video game Chocolatey, in which the character Roberto appears in a kitchen with chocolate bars on a table.

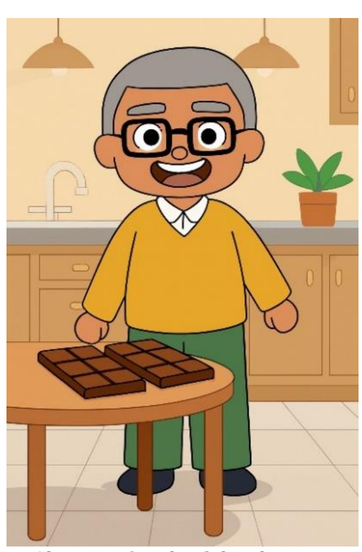

Figure 3. Shows a sketch of the character Roberto.

Following this presentation, chocolate bars are shown, and they must be broken into smaller pieces as indicated in the problem. To cut this chocolate, use the scroll bars located to the left and below the chocolate to find the denominator of the fraction (Figure 4).

Figure 4. Screenshot of the scenario showing the table with the chocolate bar and the operations to be performed.

Once the denominator of the fraction is found, the equivalent fractions of the operands must be obtained. Then, the result of the fraction operation needs to be written using the cut pieces of chocolate as a visual aid.

The game provides feedback on whether the result is correct. The more correct answers, the higher the score.

If Roberto correctly follows most of the recipes, an animation will appear showing him tasting his dessert and saying it turned out delicious. If Roberto doesn't answer correctly, he will be shown tasting his dessert with a smile, acknowledging that he did his best and that he'll do better next time.

2.2.1.3. Mischievous Spirits Video Game

An animation (Figure 5) is shown in a classroom, where teacher Susana begins reading a story from the reading book, and Alejandro is seen very attentively beginning to imagine the story in his mind.

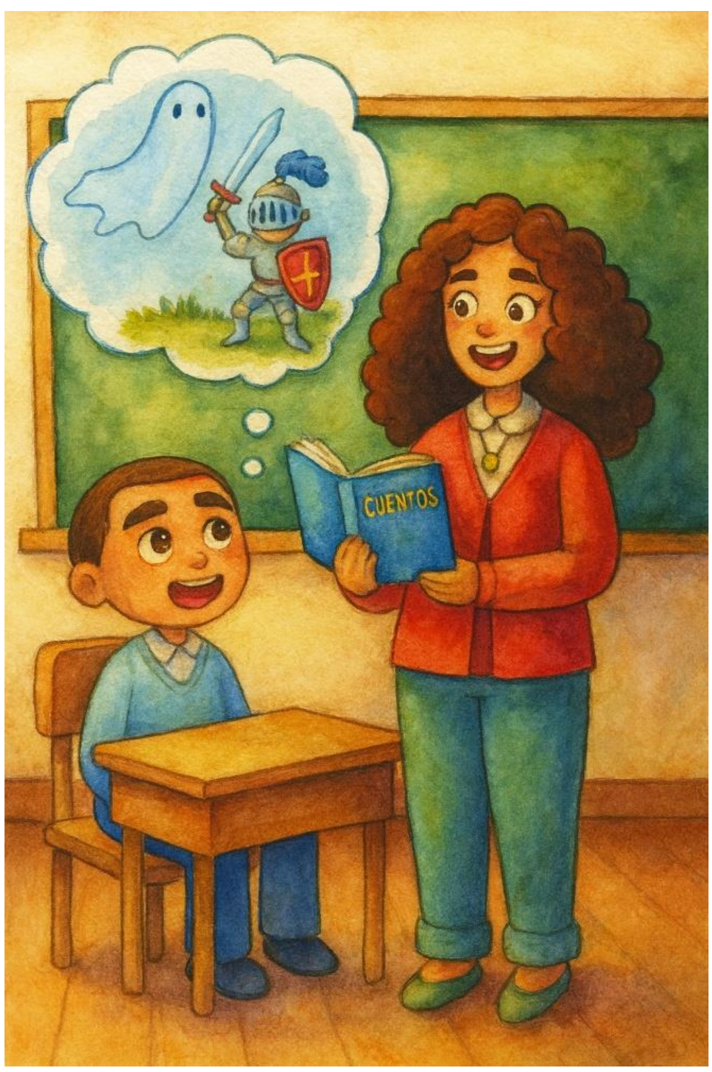

Figure 5. Shows the sketch of teacher Susana and the sketch of Alejandro.

Once inside the mind, we proceed to the game. The ghost is located in the center, and its health is displayed. Around it are slots for placing knights. At the bottom is a list of available knights and their attack damage.

The goal of the game is to place knights in the slots to accumulate the attack needed to defeat the ghost by dragging the knights from the list to the slots. The fewer knights used, the higher the score, as the intention is to use multiplication to maximize damage with the fewest knights. Once the knights are positioned, click the attack button. To attack, the player must drag the knights one by one toward the ghost to perform the attack.

If the player achieves the goal of using the fewest knights, a scene will play in which teacher Susana explains that the knights won, and Alejandro will appear very happy. Otherwise, teacher Susana will explain that the knights weren't strong enough and had to retreat to practice their strategies. Alejandro will be shown happy with the story but wishes the knights had won.

2.3. Playful Challenges for Each Video Game

The educational challenges were designed in collaboration with the teachers of Cándido Navarro Elementary School, considering the competencies and educational objectives established in the initial phase. These challenges are implicit in the playful ones, so players have fun and do not focus on the educational challenge itself. The educational challenges for each video game were defined based on the topic covered and its difficulty. Table 3 presents the educational challenges associated with the first video game, Little Races.

Table 3. Educational challenges associated with the first video game, Little Races.

ID	Educational Topic	Fourth Grade	Fifth Grade	Sixth Grade
SG1-RE1	Number	The challenges involve mentally ordering natural numbers with up to four digits.	The challenges aim to mentally order natural numbers of up to eight digits, including decimals.	The challenges aim to mentally order natural numbers up to eight digits, including decimals, and interpret numbers across the Mayan, Roman, and decimal systems.
SG1-RE2	Addition and Subtraction	The challenges involve mentally solving additions and subtractions involving natural numbers that are multiples of 100, up to four digits.	The challenges involve mentally solving additions and subtractions of natural numbers that are multiples of 100, up to five digits.	The challenges involve mentally solving additions and subtractions involving natural numbers up to three digits, including decimals.
SG1-RE3	Multiplication and Division	The challenge is to mentally solve multiplications of one-digit natural numbers by one- or two-digit numbers.	The challenge is to mentally solve multiplications of two-digit natural numbers by one- or three-digit numbers, in addition to exact divisions of natural numbers of up to three digits by two-digit numbers.	The challenge is to mentally solve multiplications of two-digit natural numbers by one- or three-digit numbers, in addition to exact divisions of natural numbers of up to three digits by two-digit numbers.

Table 4 presents the playful challenges designed for the Chocolatey video game, describing the educational topics addressed and the mathematical activities proposed for fourth-, fifth-, and sixth-grade students. The table illustrates how the challenges are adapted according to each educational level, including activities related to addition and subtraction of fractions, as well as proportionality concepts. These challenges were developed to reinforce arithmetic skills through interactive and curriculum-aligned game-based activities.

Table 4. The playful challenges corresponding to the Chocolatey video game.

ID	Educational Topic	Fourth Grade	Fifth Grade	Sixth Grade
SG2-RE1	Addition and Subtraction	The educational challenge involves solving an addition or subtraction problem involving fractions with the same denominator and quantities less than twelfths.	The educational challenge involves solving an addition or subtraction problem involving fractions with different denominators that are multiples of each other.	The educational challenge involves solving addition or subtraction problems involving fractions with different denominators.
SG2-RE2	Proportionality	Identify the correspondence between the numerator and denominator and the chocolate bars.	Identify the correspondence between the numerator and denominator and the chocolate bars.	Identify the correspondence between the numerator and denominator and the chocolate bars.

Table 5 presents the playful challenge designed for the video game "Spirits of the Mischief," specifically focused on strengthening multiplication and addition skills in fourth-, fifth-, and sixth-grade students. The table describes the educational topic addressed and the level of difficulty established according to the students' academic grade. As shown, the challenge SG3-RE1 involves solving multiplication operations combined with addition, where the complexity increases by requiring results with a greater number of digits. Fourth-grade students work with multiplications that generate four-digit numbers, while fifth- and sixth-grade students solve operations that produce five-digit numbers, allowing the activity to adapt progressively to their mathematical development.

Table 5. The playful challenges of the video game "Spirits of the Mischief."

ID	Educational Topic	Fourth Grade	Fifth Grade	Sixth Grade
SG3-RE1	Multiplication and Addition	The multiplication to be performed results in a four-digit number.	The multiplication to be performed results in a five-digit number.	The multiplication to be performed results in a five-digit number.

The following describes the challenges associated with each video game.

SG1 – Little Races

Since this game was designed as a casual serious game, the difficulty was kept relatively low, and it didn't require much time to progress. This makes it more of a way to practice the concepts covered in class.

Once the game starts, there are no pauses, so the challenge is to find the correct answer as quickly as possible or before the next question appears. To do this, the user must use their memory skills or logical thinking to solve the question quickly. This game mode can be applied to any educational.

SG2 – Chocolatey

This game is a logic puzzle because, unlike the previous one, it gives the user time to think about their question. However, the questions are open-ended, making it much more likely that the player will make a mistake. Given this type of game, there's an opportunity to delve deeper and explain the concepts involved in the educational challenge. The playful challenge involves using the available tools, such as cutting the chocolate into the desired pieces both vertically and horizontally, to find the correct answer.

SG3 – Mischievous Spirits

Like the previous game, this one doesn't have a timer. While the player has as much time as they want to answer, it incorporates more action than the previous games to make it more appealing to children. The challenge lies in choosing the right number of knights so that when the player attacks the ghost, they can defeat it. Although it involves a question-and-answer system, this is disguised by strong fantasy and role-playing or turn-based elements. Furthermore, it involves the player in the action by having them attack the ghost by dragging the knights one by one.

3. Results

This section presents information on the production phase of the video games, which were developed using all the information obtained in the two previous phases. The testing phase is also shown.

3.1. Production Phase

Once the designs were finalized, the video games were developed and integrated into the application. When a child logs in, they must create an account, which requires entering a username and password, information they will need to provide each time they log in. Figure 6 shows the application's home interface.

Figure 6. Application startup interface.

Once logged in, a screen appears that lets the child choose one of two options. One is "Learn," which contains informational videos about each video game. Choosing "Play" takes them to three video games. Figure 7 shows the interface with these two options.

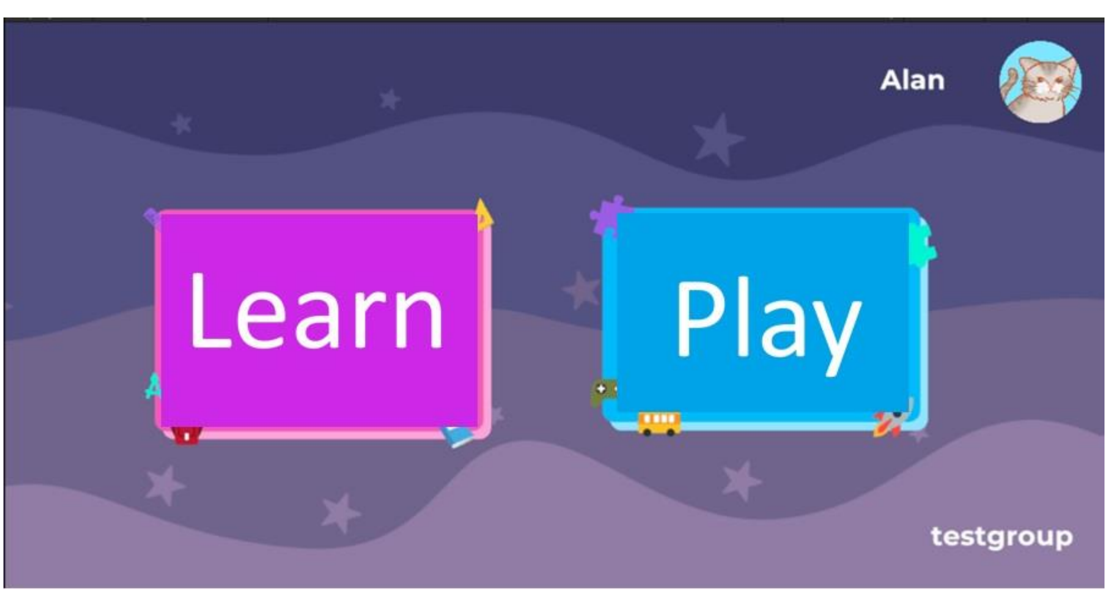

Figure 7. Interface for selecting between two options: Learn and Play.

Figure 8 shows the interface with the menu of three video games: Little Races, Chocolatey, and Mischievous Spirits.

Figure 8. Video game menu interface.

Once the child chooses a video game, they also need to select the grade, as shown in Figure 9.

Figure 9. Grade selection interface.

When the child finishes playing a video game, he/she can choose another one; you can also check his/her progress or close your session.

3.2. Graphics Engine

During the video game development phase, the Unity Technologies (2024) graphics engine was selected due to its advantages, such as its modular architecture, which allowed for the modeling of different video game elements, including characters, objects, interfaces, and scenarios. The engine also offered integrated tools for managing graphical user interfaces (UI), which allowed screens to be designed that could be adapted to different resolutions and tablet sizes, while maintaining the visual clarity required for elementary school students.

Another reason for using Unity was its multi-platform support, which facilitated exporting the project to Android devices, ensuring stable performance even on mid-range tablets used during school testing.

The engine also enabled control over the navigation flow between scenes, management of the persistence of basic player data (such as username, progress, and grades), and synchronization of animations with the educational challenges for each grade level. Thanks to its C#-based scripting system, it was possible to implement the games' arithmetic logic, validate answers in real time, and dynamically adjust the difficulty according to the grade selected by the student.

3.3. Testing

Functionality and usability tests were conducted by teachers and students at Cándido Navarro School.

To ensure the correct operation of the video games on the platform, unit tests were developed for the Unity modules. These tests verified the independent operation of the main components, such as response validation, collision detection, score calculation, and touch interaction. The consistency of navigation between scenes and the stability of the graphics engine were also evaluated during continuous gameplay. The results of the unit tests facilitated early error detection and helped debug the behavior of the video games before their implementation with students.

Usability testing was conducted at the Higher School of Computing. Over two days, 150 students from the 4th, 5th, and 6th grades participated, 75 per day, with 25 children per group and two groups per grade.

Upon arrival at the school, the students were welcomed and divided into three classrooms. They worked in pairs, and each pair was given a tablet. The tablet's functions were explained, and they then began working with the video games. Three observers were present in each classroom to assist the children with any questions. Figure 10 and Figure 11 show children working on the tablets.

Figure 10. Students from Cándido Navarro Elementary School using the educational application Chocolatey to strengthen their learning through educational video games. Photo of some children from Primaria Cándido Navarro working with video games.

Figure 11. Children from Cándido Navarro Elementary School interacting with the educational video game application Mischievous Spirits during a classroom learning activity.

At the end of the game, the children answered a questionnaire.

3.4. Validation and Reliability of the Instrument

The questionnaire consisted of eight items that assessed ease of use, perceived usefulness to the child, commitment, and the need for assistance. Seven of the items were presented in a Likert-scale format, and the eighth was an opinion question. To select an option on the Likert scale, participants used smiley faces indicating liking or disliking, as shown in Figure 12.

The following numbers were used: 1) Strongly disagree, 2) Disagree, 3) Neutral, 4) Agree, and 5) Strongly agree.

The decision to use an eight-item instrument was based on cognitive-load considerations for children aged 9–12, ensuring that the evaluation process remained concise while still capturing the key dimensions of usability and engagement.

Content validity was established through expert review by three primary school teachers, who evaluated the clarity, relevance, and age appropriateness of each item. Minor wording adjustments were made based on their recommendations.

Internal consistency reliability was calculated using Cronbach's alpha coefficient, yielding a value of 0.81, which indicates acceptable reliability for exploratory usability studies in educational contexts.

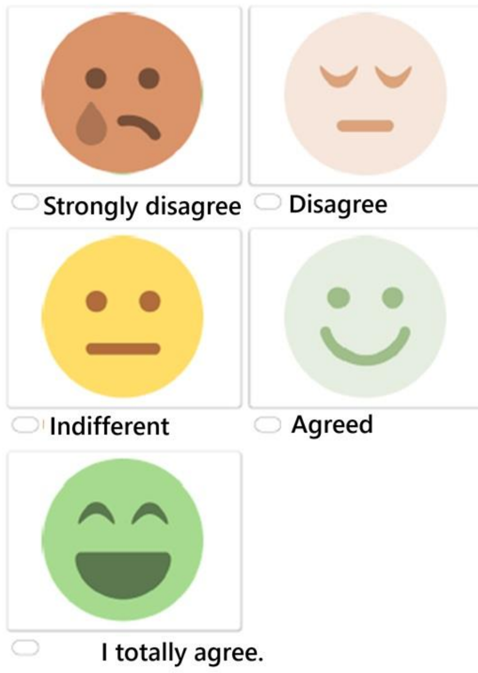

Figure 12. Likert scale response options.

Table 6 presents the results obtained from the students' evaluation of the usability and educational contribution of the video games. The table summarizes the average scores of the items related to the difficulty of use, students' experience, and the usefulness of the video games for reviewing arithmetic operations. The results indicate that students perceived the video games as easy to use, with low difficulty levels reported for each application. In contrast, the highest average scores correspond to the statements related to learning support, indicating that the video games helped students review arithmetic operations and facilitated their interaction with mathematical content. Additionally, students' opinions highlight that the challenges included in the video games contributed to maintaining their interest and motivation, with high percentages of positive responses regarding mental calculation, fraction operations, and engagement during gameplay.

Table 6. Shows the results.

Questions	Average
The Little Races video game is difficult to use.	1.5
The Mischievous Spirits video game is difficult to use.	1
The Chocolatey video game is difficult to use.	2.3
The video games helped me review arithmetic operations.	4.8
It was easy for me to use the video games.	4.3
I had to ask for help to use the video games.	2.3
What opinion would you give about the video games?	The video games were useful for mental calculation of arithmetic operations with natural and decimal numbers — 89%. Students successfully worked with fraction operations and finding equivalent fractions - 78%. The challenges presented in each video game maintained students' interest and motivation - 92%.

On average, students across all three grade levels indicated that the Little Races and Mischievous Spirits video games were easy to play, while Chocolatey was more difficult. The student sample felt that the games helped them develop their arithmetic skills.

In question 8, students' opinions about the three video games were organized into three aspects. 89% of the children focused on the usefulness of video games for developing mental calculation skills in basic operations with whole numbers and decimals, considering them helpful.

Another group of students focused on the help the video game application provided in working with equivalent fractions and adding fractions. Seventy-nine percent indicated that it allowed them to succeed in these operations.

4. Discussion

The observations taken and validated through cross-checks are as follows:

- The fourth-grade children preferred the video game "Mischievous Spirits" because it used only the set of natural numbers, and they were excited to discover how many knights they would have to attack the monsters. This translates to operating by adding the same number a certain number of times, or using a shortcut for addition through multiplication.
- A count was taken, and 56% of the children who started by adding a number several times ended up understanding that it was faster to perform multiplication; that is, they were able to realize that multiplication is a shortcut for addition. This reflects what was pointed out by Piaget, in relation to what is established in Piaget's constructivist theory (Piaget, 1969; Saldarriaga-Zambrano et al., 2016) on the processes of assimilation and accommodation; that is, in the learning process, the assimilation process is

carried out first, when knowledge reaches the mental structures, and the accommodation process occurs when it is adapted to previously acquired knowledge.

The 4th- and 5th-grade students initially struggled with the Chocolatey video game because they had difficulty finding equivalent fractions to perform operations with fractions having different denominators. Once they understood how to cut the chocolate to obtain equivalent fractions, they became very enthusiastic and were able to perform the indicated operations.

The 6th-grade students worked very well with the Chocolatey video game, quickly finding equivalent fractions.

The 4th- and 5th-grade students had difficulty performing basic operations with decimal numbers.

The 6th-grade students found solving operations with decimal numbers challenging, but they expressed satisfaction when they solved them correctly.

5. Conclusions

The work carried out with the teachers and students of the primary school with which contact was maintained was very helpful at all stages of the video game creation process. The educational objectives and competencies to be developed must be clearly defined from the initial phase, along with an institutional framework, because, in this case, the video games aligned with the curriculum, allowing teachers to use them in their classrooms to support their teaching. The story behind the video games, the playful and educational challenges, and the interactivity helped keep the students engaged throughout, thereby contributing to the development of arithmetic skills, which was the ultimate goal of creating the video games.

The study successfully met its research objectives. The study successfully met its objectives, as it resulted in the development of three educational video games for primary school children that integrated narratives, interactive dynamics, and mechanics corresponding to serious games theory, which were in line with the SEP curriculum.

Regarding the evaluation of the video games, the results showed their ease of use and usefulness in reinforcing arithmetic skills, particularly those related to mental calculation, operations with fractions, and understanding basic operations with natural and decimal numbers.

Likewise, observations made by teachers and students confirmed that the video games favored cognitive processes aligned with constructivist approaches, particularly in the transition from repeated addition to understanding multiplication, as well as in the construction of equivalent fractions. This demonstrates that the interactive environments designed were able to generate meaningful learning and promote mathematical reflection among students.

The experience gained in all phases showed that integrating playful components with clear educational objectives can effectively contribute to strengthening the arithmetic skills of elementary school students.

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