# User-Centered Design for Creating Augmented Reality Stories for Primary Education

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**Abstract.** Low motivation and reading comprehension difficulties among primary school students in Mexico are critical challenges. Despite the efforts of the Secretariat of Public Education (Secretaría de Educación Pública SEP), many students struggle to comprehend texts, impacting their academic and personal development. This work presents the development of interactive Augmented Reality (AR) stories using a User-Centered Design (UCD) approach as a means to improve reading comprehension and motivation among primary school students. The project comprises four phases: analysis, design, implementation, and testing. In the analysis phase, the needs and preferences of students and teachers were investigated. During the design phase, prototypes of interactive AR stories were created. The implementation phase involved developing these educational stories using AR technologies. Finally, in the testing phase, usability tests were conducted with 16 primary school students, collecting qualitative data through observations and questionnaires. Preliminary results showed that fourth-grade students demonstrated notable performance in understanding the interactive stories, while second-grade students found the stories and questionnaires more challenging. These observations contribute to the continuous improvement of the project by adapting the narrative and question complexity according to the educational level. The integration of AR in educational stories, combined with a UCD approach, shows significant potential for enhancing the educational experience of primary school students. This methodology not only increases reading comprehension and motivation but can also be applied in other educational contexts to foster more effective and engaging learning.

**Keywords:** User-Centered Design · Interactive Stories · Augmented Reality · Primary Education

## 1 Introduction

In Mexico, the programs established by the Secretariat of Public Education (Secretaría de Educación Pública SEP) for improving infrastructure, equipment, and materials in schools have proven inadequate or insufficient. This situation has led many teachers, in their desire to incorporate new technologies, to acquire the necessary materials with their personal income [14]. This reality highlights a problem that affects not only the teachers but also the students, who face limited opportunities to access modern and effective educational resources.

According to data provided by UNESCO, there is a worrying situation among students at the lowest level of reading performance, specifically in third grade. These students face significant difficulties in locating information in a text unless it is prominently highlighted [18]. Furthermore, UNESCO states that there is a lack of motivation among students, as teachers fail to capture their attention [18]. This lack of an essential skill not only represents an obstacle in the learning process but also compromises reading comprehension, a vital skill for the academic and personal development of students.

In an effort to improve the educational situation, the SEP implemented a significant change starting from the 2023-2024 cycle, eliminating traditional grades and adopting a "learning phases" approach. This new educational model introduces four new subjects: Languages, Knowledge and Scientific Thinking; Ethics, Nature and Societies; and Human and Community [15]. These changes are designed to address contemporary educational needs and improve student competencies.

In this context, this work focuses on the integration of Augmented Reality (AR) in the educational field as part of a search for technological proposals to address this problem. The integration of AR aims to evaluate its impact on learning, motivation, and information retention among primary school

students. Augmented reality books have proven effective in capturing and maintaining students' attention in learning [9]. More importantly, learning motivation increases when augmented reality is applied to an illustrated book [9]. However, an effort is required from educational institutions to sufficiently reinforce reading development [9].

As part of the development and implementation of these AR stories, User-Centered Design (UCD) allows understanding the user's context and needs, facilitating the implementation of technologies such as AR in the educational environment. This approach focused on developing AR stories to provide learning aligned with SEP topics. UCD ensures that technological solutions effectively adapt to the real needs of primary school students and teachers. By focusing on the direct experiences of these users, it facilitates the creation of educational tools that are not only effective but also attractive for their specific context.

This work comprises six sections. The following section, Related Work, presents an analysis of various studies that have used AR in primary education. Section three describes the model designed under the UCD approach for creating AR stories. Section four details the implementation and testing of the AR-designed stories with a group of primary school students. Finally, sections five and six offer a discussion of the approach and results, as well as the conclusions of the proposal.

## 2 Related Work

The integration of AR in the educational field aims to evaluate its impact on learning, motivation, and information retention among primary school students. Various studies have explored the efficacy and benefits of AR in improving these aspects, highlighting its potential as an innovative and motivating educational tool. Below is a comparison of several studies that have used AR in education, focusing on reading comprehension and academic motivation. Table 1 summarizes the contributions and benefits of these studies, ranging from the implementation of interactive stories to applications that use 3D models to enhance information retention.

**Table 1.** Description and benefits of AR applications

| **Author(s)** | **Description** | **Benefit** |
|---|---|---|
| Hamiyet Bursali, Rabia Meryem Yilmaz [3] | Evaluation of the impact of AR applications on students' motivation and academic performance. | 85% increase in students' motivation and academic performance. |
| Sukirman, Ika Fitri Nur Janah, Reza Arif Wibisono, Nur Subekti [17] | Use of 3D models of traditional houses to improve information retention in social studies students. | 70% improvement in information retention. |
| Veronica Rossano, Rosa Lanzilotti, Antonio Cazzolla, Teresa Roselli [13] | Use of the Geo+ application to support the learning of solid geometry by manipulating 3D geometric figures. | 90% improvement in understanding geometric concepts. |
| Johny Pretell Cruzado, Davis Huaytan Huaman, Jimmy Rodas Capa, Mirtha Quipas Bellizza [5] | Mobile application designed to improve reading comprehension through AR stories, using the agile Mobile-D methodology and combining text with visual and auditory elements. | 65% increase in reading comprehension and 55% in students' inferential memory. |
| Abbey Singh, Ramanpreet Kaur, Peter Haltner, Matthew Peachey, Mar Gonzalez-Franco, Joseph Malloch, Derek Reilly [16] | Integration of narrative elements in physical and virtual environments using avatars and specialized audio. | Improvement in the planning and organization of locative narratives, increasing user immersion and experience (no specific quantitative data). |
| Abdul Samad Danish, Nouman Noor, Onib-Ur-Rehman, Yasir Hamid, Hina Ali Khan, Rana Muneeb Asad, Agha Muhammad Yar Khan [1] | Evaluation of navigation, immersion, and visual elements in an AR application. | 80% user satisfaction with the navigation, immersion, and visual elements of the AR application. |
| Beatriz Peña-Acuña, Alba-María Martínez-Sala [12] | Use of AR stories to improve linguistic skills of immigrant children in primary education, combining text with visual, tactile, and auditory elements. | 75% improvement in favorable inclination towards AR stories, 60% increase in motivation, and 50% in students' literacy skills. |

Table 1 presents a summary of various studies that have used augmented reality (AR) applications in primary education, highlighting their benefits. These studies emphasize the positive impact of AR applications in primary education. The study [3] reports an 85% increase in motivation and academic performance, underscoring AR's potential to make learning more engaging. In [17], the visualization of 3D models improves information retention by 70%, suggesting its utility in social studies. [13] shows a 90% improvement in geometry comprehension through the manipulation of 3D figures. [5] reveals a 65% increase in reading comprehension and a 55% increase in inferential memory with interactive stories. [16] enhances the planning of locative narratives without specific quantitative data. [1] reports 80% satisfaction with navigation and visual elements. Finally, [12] shows a 75% favorable inclination towards AR stories, with increases of 60% in motivation and 50% in literacy skills among immigrant children. These studies demonstrate that AR can make learning more effective and engaging, especially when combined with visual, auditory, and tactile elements.

## 3 UCD Model Proposed

User-Centered Design (UCD) is an approach that places the end user at the center of the development process, aiming to create products or services that effectively meet their needs. This method involves the user in all stages of the process, from initial research to final testing and evaluations [7].

Based on observations from the literature, it was identified that researchers often use existing books that students already employ, but rarely create stories tailored to their educational needs. For this reason, the user-centered design approach was adopted to identify and create the necessary elements in the development of stories. These stories align with the learning themes provided by the SEP and are entertaining for the students.

This approach allows for the development of educational materials that not only meet curricular objectives but also adapt to the specific preferences and needs of the students, thereby enhancing their learning experience.

To implement UCD in the proposed model, the four phases it comprises are presented: analysis, design, implementation, and testing. In each of these phases, key elements are identified that contribute to the creation of an initial story prototype. The model is iterative and continuously refined with improvements in each iteration based on feedback and evaluations. Figure 1 presents the design with the elements found and developed throughout the first iteration of the process.

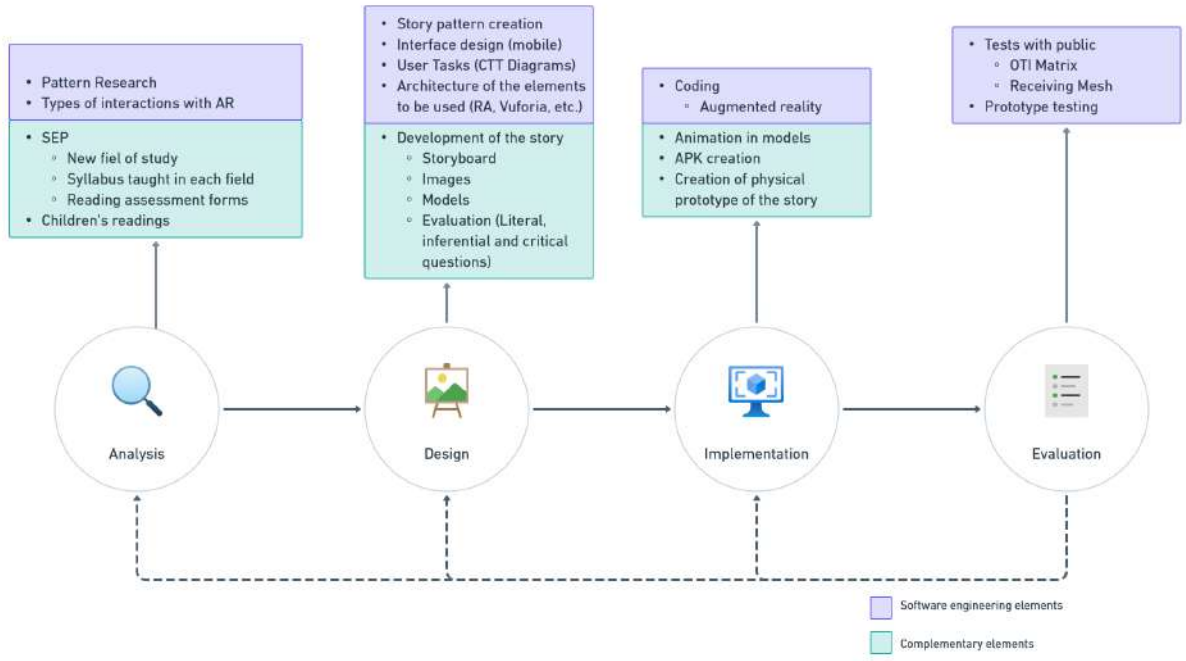


**Fig. 1.** Proposed UCD Model for Development Stories

Figure 1 presents a development model based on UCD, dividing elements in each phase into two parts: the purple part represents the identified software engineering artifacts, while the green part includes contextual artifacts identified with the help of teachers and educational experts who contribute to the design and development of the product.

The UCD approach helped ensure that the proposed model emphasizes a deep understanding of the end users and their needs, integrating this knowledge at all stages of product development. For example, in the research phase, interviews and surveys are conducted to gather requirements and analyze stakeholders, who in the educational context can be teachers and educational experts. During the design phase, wireframes and interactive prototypes are developed, validated through educational scenarios. The evaluation and refinement include usability testing and feedback, interpreted with the help of educational experts. Finally, in the implementation phase, product functionalities are developed and deployed with technical documentation and educational materials designed for effective adoption by end users. The UCD approach not only helps ensure that the product is functional but also accessible and relevant to users.

The following describes each of the phases that make up the proposed model. In each described phase, the elements for creating interactive stories using augmented reality, aimed at primary school students, are presented. The goal is to support the improvement of learning levels and reading comprehension in children, providing a learning experience adapted to the educational needs of the teacher. The proposed stories are based on the learning guidelines dictated by the SEP for basic education and include three stories: one focused on geometry learning, another on eclipses, and a third on natural ecosystems, as shown in Figure 2.

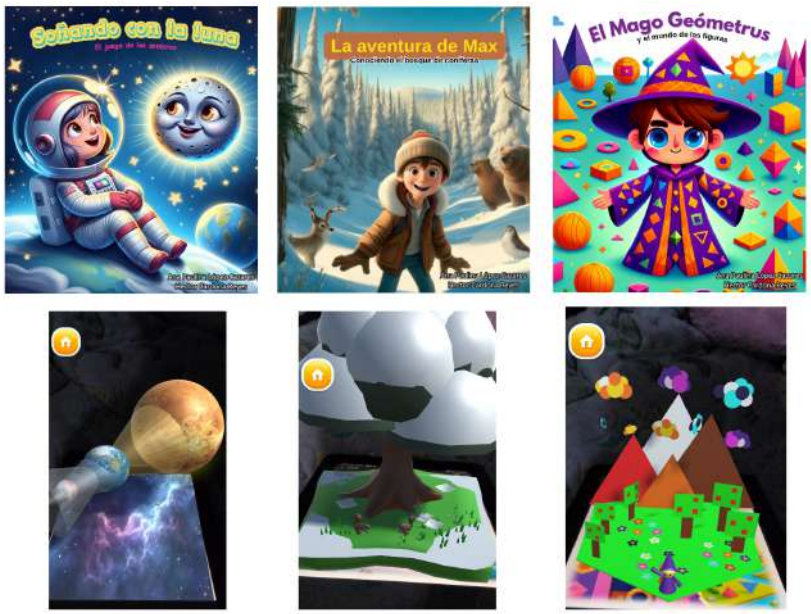


**Fig. 2.** Design of AR Stories Under the Proposed Model

### 3.1 Analysis

At this stage, user requirements and needs are identified, determining the use of the product to be developed through a thorough analysis of the users and their environment. This allows for an understanding of the context in which the work will be carried out [4]. Some of the tasks in this phase include:

**Identification of Users and Environment** This task focuses on investigating and understanding the end users and their environment. It involves conducting interviews and surveys with students, teachers, and educational experts to collect qualitative and quantitative data about their needs, expectations, and challenges. This information-gathering process helps identify user profiles, their technological skills, and the conditions under which the product will be used.

**Research on Software Engineering Artifacts and Technologies** Design patterns, programming methods, evaluation methods, and augmented reality (AR) technologies were investigated to establish a clear structure for how these elements will be implemented in the product. This includes reviewing existing literature and analyzing relevant case studies to consider best practices and technical standards for product development.

**Analysis of Educational Fields** In addition, research was conducted on the new fields of study by the Secretaría de Educación Pública (SEP) and the topics taught within each of these fields. Topics from the field of knowledge and critical thinking were analyzed and broken down (see Figure 3) to select the most suitable learning topics for designing interactive AR stories. This analysis was carried out in collaboration with teachers and educational experts to ensure that the selected content is relevant and aligned with the current educational curriculum.

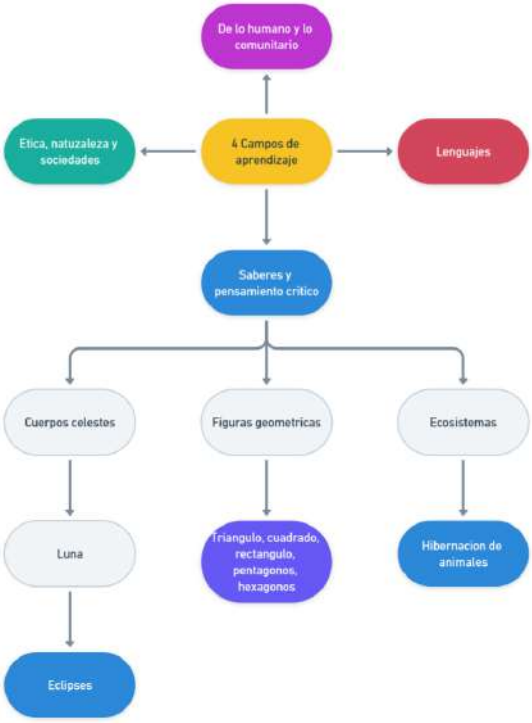


**Fig. 3.** Basic Education Fields according to the SEP.

**Evaluation of Approaches and Question Types** The SEP's approach to reading assessment was investigated, including the types of questions used in standardized evaluations. Among the types of questions evaluated were literal, inferential, and critical questions. This research included reviewing evaluation guides and observing classroom evaluation practices to design interactive AR stories that are not only educational but also effective in improving students' reading comprehension and critical thinking.

**Integration of Contextual Knowledge** All the knowledge gathered in this phase was documented and used to create detailed user profiles and use scenarios. These profiles and scenarios were essential in guiding the design and development of the product, ensuring that each decision made was based on a deep understanding of the users and their context. This user-centered approach ensures that the final product is not only technologically robust but also relevant and accessible to end users.

### 3.2 Design

In the design stage, crucial decisions are made about how to design or redesign the product, based on the knowledge obtained in the analysis stage and the usability issues discovered during initial prototyping and the evaluation of previous iterations [10]. This stage is fundamental in UCD as it allows the development team to create solutions that truly meet the needs and expectations of users. Some of the tasks in this phase include:

**Creation of User Models** This stage begins with the creation of user models, which include user profiles, personas, and scenarios. These models help to better understand the users, their motivations, goals, and usage situations [4, 6, 10]. For example, detailed profiles of students and teachers who would use the proposed stories were developed, considering factors such as their familiarity with technology, learning preferences, and specific challenges they face in the educational context.

**Development of Educational Design Patterns** Based on the analysis from the previous phase, Software Design Patterns are proposed. These design patterns are general, reusable, and proven solutions to common problems that arise during software design [8, 19, 2]. They are important in this stage as they help describe a problem that occurs repeatedly in an environment and present a solution that can be consistently applied to solve that problem, improving the efficiency and effectiveness of the software development process.

Therefore, this stage considers the creation of design patterns that enable the creation of stories aligned with the educational themes of the SEP. These patterns consider learning based on SEP themes, designing stories with specific criteria such as length, type of images, and evaluation based on SEP recommendations to assess students' understanding of the stories.

**Interface Design and Prototyping** For the design of the AR story application interface, wireframes were developed with a simple interface that allows students to visualize the augmented reality elements of the stories. Augmented reality will be visualized through targets, allowing the user to choose the story they want to read and interact with its elements. Figure 4 shows a preliminary design of the interface, with a main screen for selecting stories, viewing credits, and accessing other future options.


**Fig. 4.** Wireframes for the mobile application interface design

**Story Development and Storyboarding** For the proposed stories in Figure 2, three stories were developed following the pattern established in this stage and based on the themes selected in Figure 3. The stories created were: "Dreaming with the Moon," focused on learning about eclipses; "Max's Adventures," which addresses the fauna of the coniferous forest; and "The Wizard Geometrus," which explains geometric figures. For each story, a storyboard was created that included narrative information, image and model design, and evaluation with literal, inferential, and critical questions.

**Design of Comprehension Evaluation and Validation** Each of the designed stories includes an evaluation consisting of 8 questions: 2 literal, 3 inferential, and 3 critical. Literal comprehension questions involve understanding the exact information in the text and usually start with "What...?", "Who...?", "When...?", "Where...?" or "How...?".

Inferential comprehension questions require the student to go beyond the explicit textual information, asking the reader to make logical connections, such as interpreting characters' emotions and implicit causes and effects. These questions often start with "Why do you think...?", "What do you think...?" or "How would you explain...?".

Critical comprehension involves analyzing and evaluating the content of the texts, judging their validity, meaning, and relevance [11].

Following the UCD approach, multiple design iterations were conducted, and feedback was collected from end users, teachers, and education experts. This process allowed for refining the designs and ensuring that the final product was not only functional but also accessible, relevant, and aligned with the educational needs of the users.

### 3.3 Implementation

The implementation of the prototypes and their evaluation through usability tests and inspection methods allowed for refining the augmented reality story application. This process ensured that the application is not only functional but also intuitive and attractive to students, meeting the proposed educational objectives. By combining augmented reality technology with a user-centered approach, an effective educational tool was created that enhances the students' learning experience.

User testing involved experiments and trials directly with the designs. Inspection methods, such as heuristic evaluation, cognitive walkthrough, standards inspection, and feature inspection, involved one or more expert evaluators studying and examining the system without direct user participation [6].

With the wireframes designed, the application was coded in Unity. Using Vuforia software, augmented reality was added to the project. The application includes the stories created according to the designed pattern and selected learning objectives.

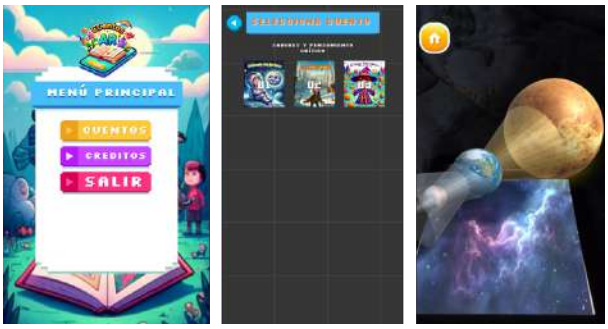


**Fig. 5.** Application interfaces from left to right: the main page, story selection, augmented reality camera to visualize the elements

With the structure of the story and images designed, a physical prototype of the stories was printed to visualize the augmented reality. Each story offered interaction with its AR elements:

- **Dreaming with the Moon:** Users could visualize the planets rotating and pause the movement to observe the position of celestial bodies, representing how an eclipse occurs.
- **Max's Adventures:** Children could explore the environment of the coniferous forest, moving the camera or the story to observe the animals in their natural habitat and see the entire landscape model.
- **The Wizard Geometrus:** Scenarios were designed where a geometric figure was hidden among other elements. Children had to find and select the different figure, and the story provided information about that figure.

### 3.4 Evaluation

The evaluation phase includes error correction and improvements based on results obtained through observation or usability surveys. This allows for software enhancement and the implementation of new functionalities based on the requirements identified during this process [4].

To carry out this phase, a test was conducted with elementary school students from second and fourth grade (see Figure 6). Teams were organized and supervised by four instructors, the necessary resources were prepared, and tools were used to extract relevant information during the work with the three stories.

**Fig. 6.** Use of AR stories in a work session with elementary school students.

### 3.5 Organization of Groups

For the implementation of the tests, groups of four children each were formed. One group consisted of fourth-grade students, and the remaining groups were second-grade students.

### 3.6 Resources

The stories were printed for the students, and each team was provided with a device to visualize the augmented reality elements of their assigned story. The fourth-grade group and one second-grade group worked with "The Wizard Geometrus," while the remaining two groups worked with "Max's Adventures."

### 3.7 Implementation of Instruments

The instruments used for data collection were the OTI matrix and the receptive grid to obtain results from the children's audience.

For the OTI matrix, a table was created to visualize the objectives, tasks, and the user interface, as shown in Table 2.

**Table 2.** OTI Matrix: Objectives, Tasks, and Interfaces.

| **Objective** | **Task** | **Interface** |
|---|---|---|
| Ensure that children read the entire story | Read the physical story | Printed story with text and illustrations guiding comprehension |
| Ensure that children select and access the correct story in the application | Choose the corresponding story in the application | Can view AR corresponding to their story by selecting the correct story in the app |
| View AR elements of each corresponding story | Explore AR elements after reading specific sections of the story | AR interface in the application |
| Complete the story's questionnaire | Answer all questions in the physical questionnaire after reading and interacting with AR | Printed questionnaire with questions and space for answers |

For the receptive grid, four questions were asked: What is the most relevant part of the story? What would you improve? What questions did the children have? and What new ideas do you have about

the experience? These questions were posed to the children to gather feedback and identify areas for improvement for a new iteration.

Based on the observations and comments from the children when answering the grid questions, a list of findings and improvement proposals was created. This is reflected in Table 3.

## 4 Results

The design proposal resulted in the creation of an application with three screens to present the stories and visualize augmented reality elements, as shown in Figure 5.

For the tests, we worked with 16 elementary students from 2nd and 4th grade, divided into four groups of four. Two groups were given the story "The Adventures of Max," and the other two were given the story "The Wizard Geometrus."

Each group was provided with a device with the application installed to visualize the augmented reality elements of the corresponding story, and at the end, they were given a physical questionnaire with questions about the story.

Data was collected using the OTI Matrix and the receptive grid, allowing us to gather opinions and observe the children's interaction with the application and the story, obtaining qualitative data and suggestions for improvement.

Table 3 of findings and improvement proposals shows the findings obtained from the opinions and observations collected through the OTI Matrix and the receptive grid, along with improvement proposals for each of these insights.

**Table 3.** Findings and Proposals.

| **Classification** | **Findings** | **Proposal** |
|---|---|---|
| Visual | The characters were pleasant | Maintain the design of the images in the story. |
| Visual | The AR visualization was enjoyable | Continue with the design of characters and environments according to the story. |
| Visual | Male characters were of interest, but it is necessary to integrate female characters | Consider introducing both female and male characters into the story. |
| Narrative | The reading was boring | Implement the Copywriting technique to adapt the narrative for younger children and improve engagement. |
| Narrative | The length of the story was overwhelming | Create shorter stories for younger children. |
| Interactive | Interaction with the models was enjoyable | Add interactions to the models, such as movement or actions. |
| Interactive | Finding hidden characters in augmented reality captured their attention | Add scenarios with more elements to allow visualization and searching for more elements in the model. |
| Interactive | The questionnaire was lengthy | For younger children, reduce the number of questions and focus on one type of question to assess comprehension. |
| Interactive | Questions were sometimes confusing due to their length | Simplify the language and structure of questions for questionnaires for younger children. Consider adding drawing exercises if convenient. |

According to the classification of general observations in the areas of visualization, narrative, and interactivity, several key points were observed. In the visual part, there were no significant complications observed in the students, although it was suggested to include female characters in the stories to improve diversity. In terms of narrative, 2nd-grade students found the stories too long and uninteresting. For this group, shorter stories will be considered, and copywriting techniques will be applied to improve the narrative and increase engagement. In the interactive part, including AR interaction and the questionnaire, additional methods will be sought to allow children to interact more with augmented reality, such as in the story of the figures, where children could find the different figure and click on it. For the questionnaires, for younger children, questions will be made more concise, and shorter questionnaires will be designed for easy completion.

For the 4th-grade students, this did not pose any problems as reflected in their questionnaire responses, but the 2nd-grade students found the story and the questionnaire lengthy. As a result, only 60

Tables 4 and 5 present the results obtained from the questionnaires administered to each 2nd and 4th-grade student for one of the stories they worked on: "The Wizard Geometrus" or "The Adventures of Max." The questionnaire consists of eight questions, divided into three categories: literal questions (2), inferential questions (3), and critical questions (3). The responses are categorized as Correct (✓), Incorrect (×), Not Answered (□), and Marked Two Options (2). The tables are broken down by grade and by story.

**Table 4.** Results of the Story: The Wizard Geometrus

| **Question Number** | **Question Type** | **Literal** | | | **Inferential** | | | **Critical** | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **Participant** | **Grade** | | | | | | | | |
| 1 | 4th | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2 | 4th | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3 | 4th | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 4 | 4th | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 5 | 2nd | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 6 | 2nd | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 7 | 2nd | ✓ | ✓ | ✓ | ✓ | □ | ✓ | ✓ | ✓ |
| 8 | 2nd | ✓ | × | ✓ | × | ✓ | ✓ | ✓ | ✓ |

**Table 5.** Results of the Story: The Adventures of Max.

| **Question Number** | **Question Type** | **Literal** | | | **Inferential** | | | **Critical** | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **Participant** | **Grade** | | | | | | | | |
| 9 | 2nd | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 10 | 2nd | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 11 | 2nd | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | □ | □ |
| 12 | 2nd | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | □ | □ |
| 13 | 2nd | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | □ | □ |
| 14 | 2nd | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | □ | □ |
| 15 | 2nd | ✓ | 2 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 16 | 2nd | ✓ | 2 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

The 4th-grade students demonstrated exceptional performance in all question categories for the story "The Wizard Geometrus," with 100% correct answers in literal, inferential, and critical questions. This indicates a strong understanding of the content and advanced critical analysis skills in this group. In contrast, the 2nd-grade students showed slightly lower performance. In "The Wizard Geometrus," they achieved 87.5% correct answers in literal questions and 83.33% in inferential questions, with some instances of incorrect and unanswered responses. Table 6 shows the percentages and correct answers according to the story and question type.

## 5 Discusion

The implementation of UCD allowed for the identification and addressing of specific student needs at each development stage. This approach facilitated the creation of interactive AR stories that not only meet the SEP's curricular objectives but are also engaging and motivating.

Some key findings from this work include:

– Attention capture with AR: The AR elements significantly captured the students' attention, demonstrating their potential as an educational tool.

**Table 6.** Results by Story and Grade

| Story | Grade | Question Type | Correct | Incorrect | No Response |
|---|---|---|---|---|---|
| **Geometrist Wizard** | 4th | Literal | 100% (8/8) | 0% (0/8) | 0% (0/8) |
| | | Inferential | 100% (12/12) | 0% (0/12) | 0% (0/12) |
| | | Critical | 100% (12/12) | 0% (0/12) | 0% (0/12) |
| **Geometrist Wizard** | 2nd | Literal | 87.5% (7/8) | 6.25% (1/8) | 0% (0/8) |
| | | Inferential | 83.33% (10/12) | 8.33% (1/12) | 8.33% (1/12) |
| | | Critical | 100% (12/12) | 0% (0/12) | 0% (0/12) |
| **The Adventures of Max** | 2nd | Literal | 87.5% (14/16) | 0% (0/16) | 0% (0/16) |
| | | Inferential | 100% (24/24) | 0% (0/24) | 0% (0/24) |
| | | Critical | 66.66% (16/24) | 0% (0/24) | 33.33% (8/24) |

- Questionnaire performance: Only 69% of the students correctly answered all the questionnaire questions, suggesting the need to balance interaction with comprehensive text reading for better understanding.
- AR visualization: All children correctly visualized the AR elements, indicating high usability of the application.
- Reading completion: 68% of the students completed the story, showing that AR is engaging but does not guarantee complete reading of the content by itself.
- Overload in 2nd grade: Most 2nd-grade students felt overwhelmed by both the story and the questionnaire, indicating the need to adjust the pacing and complexity of the content to suit different grade levels.
- Iterative feedback: The iterative UCD approach allowed for continuous adjustments based on user feedback, progressively improving the educational experience.

These findings underscore the importance of a balanced approach that combines interactive AR elements with traditional pedagogical strategies to maximize learning effectiveness. The feedback obtained in each iteration was crucial for refining the design and ensuring that the educational tools developed were both functional and engaging for the students.

## 6 Conclusions

The UCD proposed model allowed for the development of interactive AR stories that not only meet the curricular objectives of the SEP but are also engaging and motivating for primary school students. Throughout the process, continuous user feedback was collected, which was crucial for refining the design and enhancing the educational experience.

The AR elements significantly captured the students' attention, demonstrating their potential as innovative educational tools. However, the results indicated that only 69% of the students correctly answered all the questions in the questionnaire, suggesting the need to balance AR interaction with comprehensive text reading to ensure adequate understanding. Additionally, all the children correctly visualized the AR elements, indicating high usability of the developed application. While 68% of the students completed the story, this highlights that AR alone does not guarantee complete reading of the content.

It was observed that most 2nd-grade students felt overwhelmed by both the story and the questionnaire, indicating the need to adjust the pacing and complexity of the content according to the capabilities of different grade levels. The iterative UCD approach allowed for continuous adjustments based on user feedback, progressively improving the educational experience and ensuring that the developed tools were both functional and engaging.

In summary, integrating AR into interactive stories, along with a user-centered design approach, holds great potential for improving primary education. However, a careful balance is needed to ensure deep content comprehension, combining interactive elements with traditional pedagogical strategies.

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