Design and Development of an Augmented Reality Based Storytelling Platform for Interactive Solar System Learning in Primary Education

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Abstract - Concepts in primary science education, such as the Solar System, are often difficult for students to understand when presented through conventional two-dimensional learning media. This study aims to design and develop a storytelling-driven Augmented Reality (AR) learning platform to support interactive Solar System learning in primary education. A Research and Development (R&D) approach was employed, encompassing needs analysis, conceptual design, prototype development, limited trials, and formative evaluation. The developed platform enables learners to visualize three-dimensional planetary models using marker-based AR accompanied by age-appropriate narrative explanations. Limited trials involving ten fourth-grade students and two science teachers were conducted to examine usability and user perceptions. The findings indicate that students and teachers perceived the platform as engaging and supportive for visualizing abstract astronomical concepts. The novelty of this study lies in the integration of structured storytelling with AR visualization tailored for primary learners within an R&D framework. However, the results are based on formative evaluation and user perceptions; therefore, further studies with larger samples and objective learning outcome measures are recommended.

Keywords: Augmented Reality; interactive learning; primary school students; solar system; storytelling.

I. INTRODUCTION

Primary education plays a crucial role in establishing foundational knowledge and cognitive thinking patterns in young learners [1-2]. In elementary science curricula, the Solar System is introduced as a fundamental topic; however, it often presents learning challenges due to its abstract nature and the lack of direct observational experiences. Conventional instructional methods that rely on textbooks and two-dimensional (2D) illustrations are limited in their ability to represent the spatial, scalar, and dynamic relationships among celestial bodies [3]. As a result, students frequently experience difficulties in visualizing key astronomical concepts, such as planetary rotation, revolution, and relative distances within the Solar System.

To address these challenges, innovative pedagogical approaches are required to enhance student engagement and conceptual understanding. Augmented Reality (AR) has emerged as a promising technology in science education, as it enables the integration of virtual objects into real-world environments in near-real time [4-6]. Through mobile devices, AR-based learning media allow students to interact with three-dimensional (3D) representations of planets, thereby supporting abstract learning processes and improving spatial comprehension [7-9]. Previous studies have reported that the use of 3D models in science learning environments increases learner engagement, particularly when students are actively involved in observation, manipulation, and exploration activities [10-12]. Meta-analytic evidence further confirms that Augmented Reality has a significant positive effect on students' learning achievement and motivation across educational levels [13].

Beyond technological visualization, storytelling has been widely recognized as an effective pedagogical strategy for enhancing both cognitive and affective dimensions of learning. By embedding instructional content within meaningful narratives, storytelling facilitates emotional engagement and supports memory retention [14, 15]. In the context of science education, narrative-driven learning helps students contextualize complex concepts and sustain learning motivation. Consequently, the integration of Augmented Reality with structured storytelling offers an innovative instructional approach for motivating learners and supporting the understanding of abstract scientific concepts [16-18].

Although numerous studies have explored the application of Augmented Reality in science education, most existing research primarily focuses on visualization features or technical implementation aspects of AR systems. Many studies employ AR as a supplementary visualization tool without integrating structured, age-appropriate storytelling elements that align with the cognitive characteristics of primary school learners. Furthermore, prior research predominantly adopts experimental or quasi-experimental designs to measure learning outcomes, while comparatively limited attention has been given to design-oriented Research and Development (R&D) studies that systematically document the process of developing AR-based learning platforms aligned with primary education curricula.

To address these gaps, this study proposes a storytelling-driven Augmented Reality learning platform specifically designed for primary school science education using a Research and Development (R&D) approach. Unlike prior AR applications that primarily emphasize visualization features or technical implementation, this platform systematically integrates age-appropriate storytelling with marker-based AR visualization tailored to the cognitive characteristics of primary learners. The novelty of this research lies not only in combining narrative-based learning with AR technology but also in the structured application of a multimedia development framework that incorporates formative feedback from both students and teachers through limited trials. By integrating AR visualization, pedagogically grounded storytelling, and user-centered evaluation within an R&D process, this study offers a design-oriented contribution to the development of interactive science learning media aligned with Sustainable Development Goal (SDG) 4: Quality Education.

II. METHOD

This study employed a Research and Development (R&D) approach in conjunction with an interactive multimedia development model to methodically design, construct, and evaluate an educational offering that integrates Augmented Reality (AR) with storytelling for interactive science education. The R&D method was selected because it enables iterative development and refinements aligned with user input, ensuring the platform achieves its intended educational purpose. The research pathway is depicted in Fig. 1.

A. Analysis

The analysis phase involved a literature review, classroom observations, and interviews with primary school teachers and students to identify learning needs and challenges related to Solar System topics. This stage aimed to understand the limitations of conventional teaching media and users' expectations for interactive learning tools. The outcomes of this phase were used to define the functional requirements, learning objectives, and content scope of the AR-based platform.

B. Platform Concept Design

In this phase, the platform's conceptual design was developed, including the creation of storyboards, storytelling scripts, and user interface (UI) layouts. The AR learning content for each planet in the Solar System was also defined at this stage. The design emphasized age-appropriate language, intuitive navigation, and alignment with the primary school science curriculum to ensure usability and pedagogical relevance.

C. Prototype Development

The prototype was developed using Unity as the main development environment and Vuforia as the AR engine. Three-dimensional (3D) models of the Solar System planets were created and associated with image markers. When scanned using a mobile device, these markers triggered the visualization of 3D planetary objects accompanied by audio narration that explained key concepts such as planetary characteristics, rotation, and revolution.

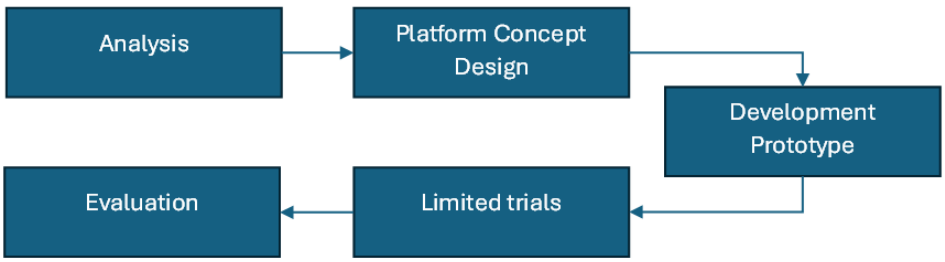

Fig. 1 Research method

D. Limited trials

The developed prototype was evaluated through limited trials involving ten fourth-grade students and two science teachers. The evaluation focused on formative aspects, including usability, practicality, clarity of content presentation, and user perceptions of learning support. Data were collected through direct observation and brief semi-structured interviews conducted during and after the trial sessions.

Given the exploratory nature of this early-stage R&D study, the evaluation was descriptive and non-inferential. The findings were intended to inform design refinement rather than measure instructional effectiveness.

III. RESULT AND DISCUSSION

A. Platform Design Results and Evaluation

An interactive learning prototype integrating Augmented Reality (AR) was developed and evaluated through a formative Research and Development (R&D) process. The platform enables learners to use mobile devices to scan image markers, which trigger the visualization of floating three-dimensional (3D) models of Solar System objects. Through this interaction, students are able to observe planetary structures and access brief, child-friendly narrative explanations introducing planetary characteristics, atmospheric conditions, and fundamental concepts of rotation and revolution. Selected unique planetary phenomena, such as extreme weather and auroras, are also presented to enrich contextual understanding. The platform results are presented in Fig. 2 to 4.

The storytelling component was deliberately designed using simple and structured language appropriate for elementary school learners. Rather than serving solely as a source of information, the narratives were intended to support learner engagement and motivation. Direct interaction with manipulable 3D objects allows students to explore spatial relationships intuitively, contributing to a more engaging and enjoyable learning experience.

The platform incorporates several interactive instructional aids designed to facilitate comprehension and support learning processes. Visual interactivity and imagery assist learners in addressing challenges associated with abstract scientific concepts by contextualizing instructional content related to planetary motion, scale, and spatial relationships through three-dimensional representations.

Fig. 2 Main menu of the AR Solar System Application

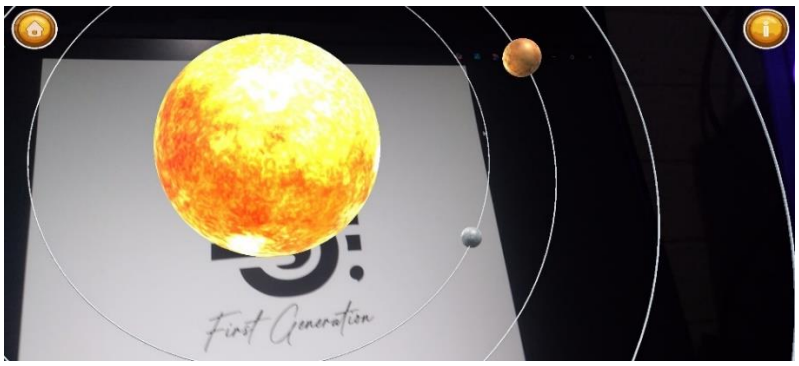

Fig. 3 Visualization of 3D planetary objects using image markers

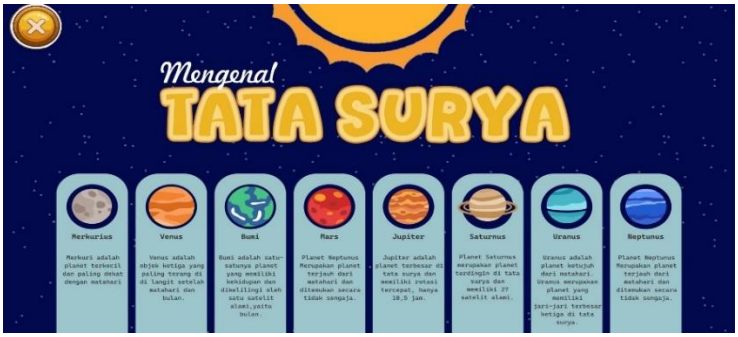

Fig. 4 Materials of the Solar System

Formative evaluation was conducted through limited trials involving ten fourth-grade students and two science teachers. The evaluation focused on practicality, usability, and user perceptions of learning support, rather than objective measurement of learning outcomes. The results indicate that nine out of ten students (90%) reported higher learning enthusiasm when using the AR application compared to traditional textbook-based instruction. Students also perceived that the 3D visualizations supported their understanding of Solar System concepts that were previously difficult to visualize using conventional learning media as shown in Table I.

Table I presents students' responses obtained during formative evaluation and reflects their perceptions of usability, motivation, and perceived learning support, rather than objective learning achievement. In addition, teachers provided constructive feedback indicating that the platform supported the explanation of abstract scientific concepts such as planetary rotation and revolution. Several suggestions for improvement were identified, including enabling more flexible resizing of 3D models for classroom demonstrations and enhancing audio narration clarity to better support blended learning environments.

The development results indicate that an interactive learning platform combining Augmented Reality (AR) and storytelling can be utilized as a supportive medium for primary science education. Based on limited trial implementation, the use of three-dimensional visualizations accompanied by simple narrative explanations assisted students in forming initial mental representations of Solar System concepts that are difficult to convey through two-dimensional learning materials.

These findings reinforce existing perspectives that AR has the potential to support science learning by providing more concrete visual representations of abstract concepts. Direct interaction with three-dimensional objects enables learners to explore scientific phenomena more actively, contributing to a more meaningful learning experience. This observation is consistent with previous studies highlighting the role of AR in enhancing visualization and learner engagement in education [19-22]. However, within the scope of this study, the observed benefits primarily reflect learners' experiences and responses toward the developed media.

User interface (UI) and user experience (UX) design were also found to influence the usability of the AR-based learning platform. A simple interface, intuitive navigation, and clear visual presentation supported students in interacting with the application without excessive technical difficulty. By minimizing unnecessary cognitive demands related to system operation, learners were better able to focus on the instructional content. This finding further emphasizes the importance of integrating sound UI/UX principles in the development of educational technology [23-25].

In addition to visual representation, storytelling elements contributed to learner engagement by presenting scientific information within a structured and coherent narrative. Narrative-based explanations helped students follow the learning content more easily and maintain attention during the learning process [26]. While storytelling appears to support engagement and accessibility of information, its direct influence on conceptual mastery cannot be conclusively determined within the limitations of the current formative evaluation.

Several limitations emerged during the implementation of the prototype. Technical issues related to marker sensitivity, camera handling, and variability in device performance affected the consistency of user experience across participants. Furthermore, the limited scope of the trials restricts the extent to which the findings can be generalized. As this study represents an early-stage Research and Development (R&D) effort, the results should be interpreted as preliminary insights intended to inform design refinement rather than as evidence of instructional effectiveness.

TABLE I
STUDENT RESPONSES TO THE AR-BASED SOLAR SYSTEM LEARNING PLATFORM

No	Evaluation Aspect	Positive Response (%)
1	Learning motivation	90%
2	Ease of understanding Solar System concepts	90%
3	Interest in learning using AR media	90%
4	Clarity of 3D visualization	80%
5	Ease of application use	80%

Overall, the developed platform demonstrates potential for further development and adaptation to other science topics. Future studies involving larger participant groups and more comprehensive evaluation approaches are necessary to gain deeper insight into learning outcomes. Within its current scope, this study contributes to the design and formative evaluation of an AR-based storytelling learning platform that supports learner engagement and perceived understanding, aligning with the objectives of Sustainable Development Goal (SDG) 4: Quality Education.

IV. CONCLUSION

This study presents the design and formative evaluation of an interactive learning unit that integrates Augmented Reality (AR) and storytelling for Solar System topics in primary education. The developed prototype utilizes mobile devices and image marker scanning to display three-dimensional (3D) planetary models accompanied by age-appropriate narrative content. Based on limited trials, students and teachers perceived the platform as engaging and supportive in visualizing abstract scientific concepts, such as planetary rotation and revolution, which are often challenging to convey through conventional instructional media. The findings suggest that the integration of AR and storytelling has the potential to support learner engagement and perceived conceptual understanding in primary science learning. However, the results are derived from user perceptions obtained through formative evaluation and should not be interpreted as evidence of instructional effectiveness. This study is subject to several limitations, including a small sample size and technical constraints related to marker interaction and audio narration quality, which limit the generalizability of the findings. Future research is recommended to involve larger and more diverse participant groups, employ validated evaluation instruments, and incorporate objective assessments of learning outcomes. Further refinement of technical features and content scalability may also enhance the applicability of the platform in broader educational contexts. Within its scope, this study contributes to the development and early evaluation of an AR-based storytelling learning platform that supports learner engagement and aligns with the objectives of Sustainable Development Goal (SDG) 4: Quality Education by promoting inclusive and innovative digital learning experiences.

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