Augmented Reality technology as a strategy to enhance learning of spatial astronomy concepts in the 7th grade

Inês Mendes

DigiMedia, Aveiro University, Campus Universitário de Santiago, Aveiro, 3810-193, Portugal

Abstract

Understanding basic astronomical concepts requires spatial thinking, particularly the ability to imagine and interpret 3D models. Difficulties in fully comprehending these concepts can adversely affect students' understanding of educational content and their attitudes towards science, leading to persistent misconceptions in astronomy. This study aims to develop an educational conceptual model to understand, frame and guide the process of incorporating Augmented Reality technology into 7th grade astronomy teaching. Based on the Educational Design Research methodology, fieldwork will be carried out involving experimental and control groups. The impact of the experience will be analysed, namely in terms of students' performance, motivation for learning and overcoming diagnosed misconceptions.

Keywords

Augmented Reality technology, spatial thinking, misconceptions, astronomy, 7th grade

1. Introduction

Studying astronomy concepts with a high degree of abstraction requires spatial thinking skills [1]. Due to that, difficulty in fully grasping these complex concepts can have a negative impact on both the understanding of educational content and students' attitudes towards science, fuelling lasting misconceptions in astronomy [2], [3].

Given this problem, using Augmented Reality (AR) in education context may be the key to enhance a better perception of spatial thinking and therefore of astronomical phenomena [4]. Besides that, using AR technology in education has demonstrated to attract a lot more attention and interest from the students, motivating them to learn [5].

Thereby this study aims to investigate which characteristics an educational experience that incorporates AR technology should have, in order to qualify the learning experience of astronomy spatial concepts, in terms of students' attitudes, misconceptions overcoming and academic achievements.

It is worth to be mentioned that the motivation to carry out this research, as well as its thematic delimitation, results mainly from the reality felt by the main researcher of this study, as a physics teacher, with fifteen years of teaching experience, and direct observer of this problem with her students, namely their difficulty in perceiving 3D models of the stars, as well as the underlying phenomena.

The following *theoretical background* is presented, the *problem*, *research question* and *goals* are identified, the *phases* and *methodology* to be used are detailed, as well as the *progress so far*.

2. Theoretical Background

In order to understand the research being carried out, the following explore the importance of learning astronomy, how misconceptions in this field can affect the learning process and how AR can support to overcome (or prevent) these misconceptions.

2.1. Know Astronomy. What for?

Astronomy has not only always sparked man's interest, it has also helped him to understand the Universe that surrounds us, so it is understood that its history involves a period of time as old as human origins [6].

Technological development has led to a change in the paradigm of astronomy, which is now a science that studies the Universe origin and evolution [7]. Investing in astronomy is investing in the future, since the instrumentation and computer skills applied to this science fosters skills crucial for success in a technology-driven workforce.

In Portuguese curriculum, 7th grade students need to understand (among other subjects) the structure of the solar system, rotation and revolution of earth and moon, and their impact on life on earth (and in their own lives) [8].

2.2. Misconceptions in Astronomy

Studying astronomy can be self-motivating, due to its aesthetic beauty and the curiosity to understand the

Proceedings of the Doctoral Consortium of the 19th European Conference on Technology Enhanced Learning, 16th September 2024, Krems an der Donau, Austria

ines.mendes@ua.pt (I. Mendes)
0000-0003-2537-4917 (I. Mendes)

universe around us [9], still, understanding astronomical phenomena requires the ability to imagine and interpret 3D models, most often represented in 2D form (e.g. in books), and to follow their movement in three-dimensional space, which Cole et al. [1] defines as "spatial thinking skills". Indeed, astronomy topic categorize to science macro, in that sense, the objects being discuss here are very large and abstract. Regard to this, 7th grade students use their perceptual and cognitive abilities to build mental models, combining what they are currently learning with what they have previously learnt [1]. However, these models are not always in line with what is scientifically accepted today, causing persistent misconceptions [2], which Comins [10, p.56] define as "any deeply held belief that is inconsistent with currently accepted scientific concepts". This author emphasizes how the existence of these beliefs does not mean that his students are not intelligent, reinforcing that it is inevitable as we all develop alternative ideas about the natural world.

To prevent these alternative ideas from affecting the learning process, Cox et al. [11] state that teachers first need to be aware of these alternative ideas, and Slater et al. [12] reinforce the importance of diagnostic assessment for students. Both authors identify that a common misconception on this field is students' belief that the seasons result from the changing Earth-Sun distance, having Slater et al. [12] pointed out that students explain the phases of the Moon in terms of the Earth blocking the Sun's light, which creates a shadow across the Moon.

Misconceptions, frequently based on common sense, are deeply rooted, so the promotion of conceptual change needs a clear confront with it evidencing the gap that needs to be surpassed.

2.3. Augmented Reality to support spatial thinking

Given that understanding astronomical phenomena requires spatial thinking skills and the ability to imagine and interpret 3D models, there is a clear need to enrich students' learning environments, to amplify their visual and intellectual engagement, which can be achieved through the use of technology [13]. AR is a technology that provides a means and brings the opportunity to visualize objects in 3D and its study in their entirety, having demonstrated to be far more effective than learning with 2D objects or models [4], [14].

Sahin et al. [13], observed in controlled groups of students, that when the contents were taught using AR, they were more effectively learned than with conventional teaching-learning methods. It was observed that the levels of interest and positive attitude towards the lesson and its content were much higher when using AR technology. In the same study, it was concluded that with the use of AR, students were able to visualize physically abstract concepts through virtual objects in 3D, and therefore in a much more enjoyable teaching-learning process, resulting in better school results. Besides the ability to improve spatial thinking, the use of AR technology in education attracts a lot more attention from the students, motivating them to learn [5].

3. Problem, Research Question and Goals

Considering the arguments set out in the previous chapter, the research **problem** arises from *the difficulty in visualizing abstract concepts and spatial cognition associated with learning of astronomical phenomena.*

Assuming that spatial cognition impacts the understanding and visualization of abstract astronomical concepts, namely seasons and moon phases, this study aims to investigate how the use of AR technology can be configured as an effective pedagogical approach to improve the understanding and visualization of these abstract concepts, in order to enhance the teaching-learning process in the field of astronomy. In this way, we seek to answer the overarching **Research Question** (**RQ**):

How can Augmented Reality technology qualify the educational experience of astronomy spatial concepts in the 7th grade, in terms of students' attitudes, misconceptions overcoming and academic achievements?

Throughout the research, we will address the following three working questions:

RQ1 What are teachers' perceptions of students' misconceptions in astronomy?

RQ2 What are teachers' perceptions of the use of AR in astronomy teaching?

RQ3 What features should an AR technology have to overcome the identified difficulties?

Thus, the main **goal** of this investigation is to develop a conceptual model on the educational experience of astronomy based on AR technology. To this end, an educational experience with the incorporation AR will be design, developed and evaluated, which hopefully will make it possible to improve the understanding of specific phenomena/concepts in the "Space" domain, that are included in the 7th grade astronomy teaching activities.

4. PhD Plan

In order to answer the identified RQ, a study was orchestrated (nationwide) in close proximity to the educational process main players. For the topic under study, these were the students attending the 7th grade and the physics teachers teaching this subject. Below, we have the phases of the study and the follow-up methodology approach.

4.1. Phases

In terms of research design, this study is framed within sequential exploratory research of three phases (with their respective stages): *exploratory study*, *prototyping* and *analysis*.

4.1.1. Exploratory study

In the first stage (**S1**) of the study a theoretical framework was drawn up, surveying existing digital technologies to support the teaching of these concepts, considering digital resources suitable for the introduction, exploration and consolidation of this domain.

As part of the research, an exploratory cycle (**S2**) was carried out (in a real classroom context, with 7th grade students and their teacher) to prepare the educational experience for the next stages, in which an exploratory prototype of an AR application was designed, developed and evaluated (in the context of a partnership and (first) master's degree supervision). This proof of concept made it possible to understand the main aspects, limitations and challenges of the real interaction environment, and was a crucial exploratory stage for subsequent decisions.

This was followed by a stage to characterise the educational experience of teaching astronomy in the 7th grade (**S3**), and consisted of two moments: the teachers' questionnaire and the focus group.

The aim of the questionnaire was to understand teachers' organisational practices (in terms of strategies and resources) with regard to the teaching and learning of astronomy concepts taught in the 7th grade, to identify the main difficulties associated with teaching, and to understand teachers' perceptions on the use of digital technologies to optimise the teaching and learning process. Descriptive and inferential statistics were the data analysis techniques for this quantitative approach, with the support of IBM SPSS analysis software. After analysing the answers to the questionnaire, a second cycle was implemented, this time by consulting experts (physics teachers with teaching experience on the topic under study) using the focus group technique. The data collected from this qualitative approach was analysed with the Thematic analysis technique.

4.1.2. Prototyping

Considering the decisions made in the previous phase, the prototyping phase of the study began, with the core aim of designing, developing and evaluating the educational experience, including a prototype using AR technology.

In the design stage (**S4**), the didactic specifications of the educational experience were defined, such as the educational content to be analysed in the study with the students, as well as the expected learning. With the implementation of the experiment in mind, and mentally anticipating the desired results in order to formulate the theoretical assumptions, we reflected on and planned the sequence of the educational experiment, for example by producing sketches of the teaching and defining the characteristics of the pre- and post-test to be implemented. Bringing the AR immersion innovative component to this experience, a functional AR prototype was designed as part of a (second) supervision of a master student's project. Through regular team meetings, and combining with the constructs that emerged from the teachers' questionnaire and focus group, the application's graphic and functional specifications were defined, with low-fidelity validation. Summing, it was deliberated the users' learning goals/objectives, learning approach and tasks/activities.

Implementing what was conceptualised (**S5**) in the previous stage, the entire educational experience is being developed to translating the theoretical assumptions into projects, such as producing the teaching scripts to be used by the students, drawing up/adapting the (pre/post) questionnaire for implementation of the study, drawing up observation grids, as well as specifying the timings of the implementation of the study, taking into account the specifications of the school calendar.

Linked to the technology materialisation to be used during the experiment, a process marked by evaluation and revision are taking place, through several working meetings with the research team, to build and refine the prototype to be used in the intervention. A high-fidelity evaluation of the prototype will then be carried out, using a convenience sample and checklists for verification.

Before carrying out the evaluation with the end users, the educational experience will be trialled with the focus group teachers and students.

In this final phase of prototyping (**S6**), what had been developed will be transformed into practical action and the effectiveness of the intervention will be tested. During the evaluation stage, both the experimental and control groups of 7th grade students will be assessed while the educational experiment is implemented in an actual classroom context.

A testing technique will be used whose data collection instruments will be the pre- and post-test questionnaire (to gauge knowledge acquisition in the area under study), field notes and observation grids (collected during and after the lessons being analysed) and multimodal student records (such as worksheets). During this implementation stage, the study will try to collect data on the process of student interaction with the AR technology developed in order to gauge student motivation (motivation test), the degree of interaction ease with the technology, as well as overcoming previously diagnosed difficulties. It will also try to understand the students' level of spatial thinking (spatial thinking test).

4.1.3. Analysis

Correlating the data collected in the two previous phases, this stage (S7) of the empirical study will analyse and reflect on the impact of the educational experience on student performance. It is believed that this correlation will make it possible to draw fruitful conclusions and will bring the data needed to draw up the instructional design model.

In chronological order, the stages overview of the empirical study is displayed in Table 1.

4.2. Methodology approach

Given the dynamic nature of the educational context and the complexity of inherent variables, this study was strongly influenced by Educational Design Research (EDR) approaches, which stems from the search for innovative educational strategies. EDR uses research as a form of intervention based on the environment in which it takes place [15], aiming to present practical solutions with effective changes, therefore producing scientific knowledge [16]. Considering that this methodology is based on iterative development cycles, in this research stages S1-S3 correspond to a first cycle and S4-S6 to a second cycle.

Any research presumes the construction of new knowledge, and it is essential to choose the method for understanding the reality to be investigated. Considering this, the research has a mixed epistemological position, sharing some features of the interpretive paradigm (since the research team had a participatory position at the early stages S1-S3) and others of the post-positivist paradigm (totally independent of the observer, resulting from a comparative and objective analysis between control and experimental groups, S6-S7) [16].

An overview of the context, the boarded research gap, the research question, goals, planned contributions and planned evaluations can be found in Figure 1.

5. Progress so far

At this point, the author had already conducted the stages S1, S2, S3 and S4, and is currently conducting the stage S5.

Regarding **S1**, and considering only free resources, the review showed that there is a gap of digital technologies to support the educational process of basic astronomy concepts. Actually, it was found that some applications support students’ motivation and arouse interest, but they are not designed to support abstract concepts teaching (with scientific accuracy). Particularly regarding to AR technologies for astronomy, the gap is even wider. Even though, from this survey, it was possible to collect some beneficial functional and graphic specifications, guiding future necessary decisions, particularly those related to learning management components to be integrated into the technology to be developed.

Regarding stage **S2**, dimensions related to exploratory prototype usability were evaluated, in the context of Day and Night specific school curriculum. An android prototype was created using Unity 3D and Vuforia Augmented Reality library. The application was designed to be used by 7th grade students (sample of 16 students) during a physics class (Figure 2), considering the use of mobile devices, with the AR prototype previously installed. Analysing the data collected from the usability test, it was possible to note that:

- Although all students presented technological skills, it was noticeable that not all were familiar with AR technology;
- Based on the responses from the post-test and direct observation, students' interaction with technology was overwhelmingly positive and enthusiastic to the use of this technology;

Phase	Stage
☆ **Exploratory study**	**S1.** State of the art survey **S2.** Exploratory prototype **S3.** Characterisation of the educational experience
☆ **Prototyping the educational experience**	**S4.** Design **S5.** Development **S6.** Evaluation
☆ **Analysis and reflection**	**S7.** Analysis of results

Table 1. Empirical study: phases and stages.

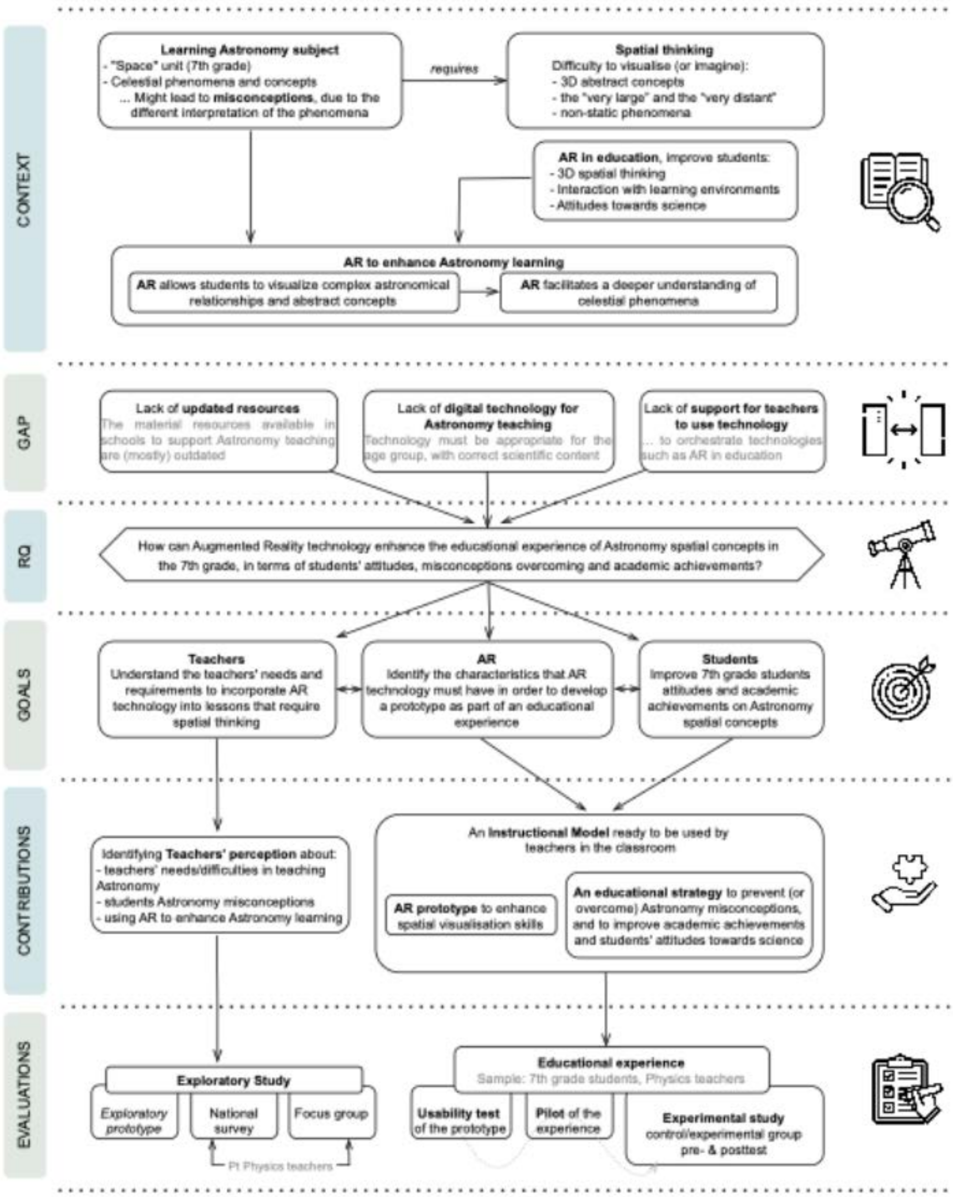

Figure 1. Thesis diagram.

- Students referred the visualization of the Earth as a 3D object easier to understand because of the AR possibility of interaction, so they could see the other side of the Earth not having to imagine – "(in 2D) you don't understand where the light goes" [17, p.257];
- Overall, AR technology is easily accessible to students of this age group, facilitates 3D visualization, and promotes motivation in the school content covered.

To characterising the experience stage (S3), it was developed and validated (with a pilot test) a closed and structured questionnaire, categorised by four dimensions:

1. Socio-professional context;
2. Organisational practice;
3. Teaching/learning astronomy issues;
4. Digital resources and astronomy teaching and learning optimisation.

Figure 2. Usability evaluation photo of the exploratory prototype [17, p.257].

This data collection instrument was sent to the (middle and secondary) school Portuguese physics teachers in an online format (LimeSurvey), and 381 answers were considered for analysis (10,1% of the physics teachers teaching in Portuguese public schools in 2021/22). From the statistical analysis, stands out that (teachers' perspective):

- The factors that most affect the learning of the "Space" domain are the lack of students' commitment/attention and the difficulty of visualising the stars and their 3D phenomena;
- The three curricular contents that are most difficult for teachers to teach, are "Seasons", "Distinguishing between the weight and mass of a body" and “Eclipses”;
- When asked how often they used digital technologies to support their teaching, 87,7% of teachers said they used them at least once a week or in every lesson;
- When asked about their opinion on the use of mobile devices in the classroom, 68,7% of teachers agreed or totally agreed;
- When asked about their familiarity with AR technology, it was found that 40,7% of the teachers had little or no familiarity at all, with only 23,4% claiming to have used it in educational contexts;
- 58,6% of teachers stated that the reason for not having used AR was because they were "unaware of related technologies";
- 34,6% of teachers consider it likely or very likely that they would use AR technology when teaching "Space" contents.

A second stage to characterise the experience took place with the implementation of a focus group (through video conference), which brought together five physics teachers, teaching in different geographical areas of the country and with the minimum of eight years of teaching experience on the topic under study. The master student (frontend web and app developer), as member of the research team, also took part in the session. This focus group was structured using a carefully prepared script. Using the observation grid and the audio recording of the session, the data collected was analysed using Thematic analysis, and the following deliberations and conclusions emerged:

- Considering that the "Seasons" is one of the most difficult topics for students, it was unanimously agreed that it could most benefit from the use of AR in teaching, due to its ability to facilitate 3D visualisation;
- It was reinforced that the narrative adopted for the technology should not be too infantilised, preventing students from becoming demotivated;
- For the implementation in the classroom, three moments have been suggested: a first one where students are exposed to AR prototype, allowing it to be explored freely, to arouse interest and motivation, starting from a guiding problem question; a second moment where teachers will make use of more "traditional" teaching strategies, such as textbooks and videos; and a third moment where students interact with the prototype again, this time in a guided way, working in groups to consolidate the knowledge acquired;
- Realising the need to diversify teaching methodologies in order to maintain student interest and promote more effective learning, the following methodologies were suggested: flipped classroom; problem-based learning; and collaborative learning.

Based on the state of the art carried out in S1, on the main limitations and challenges identified in the exploratory prototype S2, as well as considering the main conclusions of the questionnaire and focus group S3, the prototyping phase began with the design of the educational experiment (**S4**). The topics selected for the study were “the seasons”, but also the “the moon phases”, as these were the ones where the students could benefit most from 3D visualisation. The didactic specifications suggested in the focus group were considered for this design, such as the concern with the narrative, the teaching sequence and the teaching methodologies to be adopted. The didactic guide outlines were designed considering e.g. presentations, videos, worksheets, quizzes. The functional design of the AR prototype was implemented (Figure 3), with a low-fidelity validation, using a convenience sample.

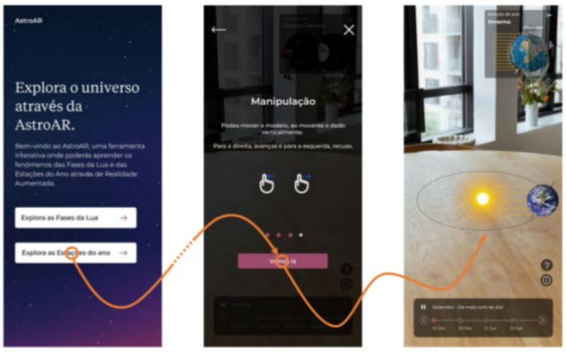

Figure 3. Functional images of the prototype (in Figma).

Finally, an educational experience is currently being developed (**S5**), considering the integration of an AR prototype, which has been named AstroAR.

These are the stages taken so far, and the following steps are:

- finishing the development with a usability test, and the respective adjustments (October);
- evaluation with experimental and control group (January);
- analysis (February/March);
- thesis defence (July).

Acknowledgements

This PhD research is funded by the Portuguese National Funding Agency for Science Research and Technology ("Fundação para a Ciência e a Tecnologia – FCT) with grant reference 2022.11815.BD. The author would like to express gratitude to her supervisors, Mário Vairinhos and Isabel Malaquias, for believing and supporting this project, as well as Mariana Bela and Joana Cunha, master students who participated in the design and development of the two AR prototypes of the study.

References

[1] M. Cole, C. Cohen, J. Wilhelm, and R. Lindell, "Spatial thinking in astronomy education research," *Phys Rev Phys Educ Res*, vol. 14, no. 1, p. 10139, 2018, doi: 10.1103/PhysRevPhysEducRes.14.010139.

[2] M. Baybars and S. Can, "Middle School Students' Misconceptions about the Concepts of Astronomy," *International Education Studies*, vol. 11, no. 11, p. 34, 2018, doi: 10.5539/ies.v11n11p34.

[3] M. Cole, C. Cohen, J. Wilhelm, and R. Lindell, "Spatial thinking in astronomy education research," *Phys Rev Phys Educ Res*, vol. 14, no. 1, p. 10139, 2018, doi: 10.1103/PhysRevPhysEducRes.14.010139.

[4] H. K. Wu, S. W. Y. Lee, H. Y. Chang, and J. C. Liang, "Current status, opportunities and challenges of augmented reality in education," *Comput Educ*, vol. 62, pp. 41–49, 2013, doi: 10.1016/j.compedu.2012.10.024.

[5] M. Sirakaya and E. K. Cakmak, "The effect of augmented reality use on achievement, misconception and course engagement," *Contemp Educ Technol*, vol. 9, no. 3, pp. 297–314, 2018, doi: 10.30935/cet.444119.

[6] J. R. Percy, "Astronomy education: An international perspective," *Astrophys Space Sci*, vol. 258, no. 1–2, pp. 347–355, 1997, doi: 10.1023/a:1001768231516.

[7] J. Retrê et al., *Big Ideas in Astronomy: A Proposed Definition of Astronomy Literacy*. 2019.

[8] D. G. da E. DGE, "Aprendizagens Essenciais de Físico-Química 7.o ano - 3.ociclo do Ensino Básico." 2018.

[9] R. Bartelmebs and R. Moraes, "Contribuições do Construtivismo para o Ensino de Conteúdos de Astronomia nos Anos Iniciais," Schème - *Revista Eletrônica de Psicologia e Epistemologia Genéticas*, vol. 4, no. 2, pp. 73–90, 2012.

[10] N. F. Comins, *Heavenly Errors. Misconceptions About the Real Nature of the Universe*. Columbia University Press, 2001.

[11] M. Cox, A. Steegen, and M. De Cock, "How aware are teachers of students' misconceptions in astronomy? A qualitative analysis in Belgium," *Science Education International*, vol. 27, no. 2, pp. 277–300, 2016.

[12] E. V. Slater, J. E. Morris, and D. McKinnon, "Astronomy alternative conceptions in pre-adolescent students in Western Australia," *Int J Sci Educ*, vol. 40, no. 17, pp. 2158–2180, Nov. 2018, doi: 10.1080/09500693.2018.1522014.

[13] D. Sahin and R. M. Yilmaz, "The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education," *Comput Educ*, vol. 144, no. December 2018, p. 103710, 2020, doi: 10.1016/j.compedu.2019.103710.

[14] C. Lindner, A. Rienow, and C. Jürgens, "Augmented Reality applications as digital experiments for education – An example in the Earth-Moon System," *Acta Astronaut*, vol. 161, pp. 66–74, 2019, doi: 10.1016/j.actaastro.2019.05.025.

[15] J. Akker, "Curricular Development Research as a Specimen of Educational Design Research," in *Educational design research / Part A: An introduction*, T. Plomp and N. Nieveen, Eds., SLO, 2013, pp. 52–71.

[16] S. Mckenney and T. C. Reeves, CONDUCTING EDUCATIONAL DESIGN RESEARCH. Routledge, 2012.
[17] M. Bela, I. Mendes, and M. Vairinhos, "An Augmented Reality Application to Better Understand 3D Astronomy Concepts in the 7th Grade," in *Proceedings - 2023 IEEE International Conference on Advanced Learning Technologies*, pp. 255–257.
doi: 10.1109/ICALT58122.2023.00081.