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Doctoral Colloquium—Students as Designers of Augmented Reality Artifacts: Learning Experience and Impact on Learning

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Abstract. Over the past 18 years, Augmented Reality (AR) has become a significant innovation in education, with many studies exploring its integration into teaching. These studies often focus on the perceptions, attitudes and acceptance of AR by both teachers and students, as well as its impact on student learning, including improvements in knowledge, motivation, school climate and skills like collaboration and problem-solving. Another area of research evaluates the development and testing of AR applications. However, there is a research gap in exploring students as creators of AR content for their own learning. While prior studies on digital technologies emphasize the benefits of students designing digital tools, little research has examined the impact of students designing their own AR applications. Active participation in such design processes (e.g., while designing digital games) has been shown to enhance engagement, improve attitudes toward learning and develop 21st century skills. This doctoral colloquium aims to address this gap by investigating how students' creation of AR artifacts influences their learning experiences, motivation, and knowledge, exploring their perceptions during the design process.

Keywords: Augmented Reality (AR), Students as Creators, Learning Outcomes.

1 Introduction

Nowadays, Augmented Reality (AR) is an emerging technology in education, combining virtual and real objects in real time [1-2]. The existing research that has accumulated over the last 15 years regarding the utilization of AR in education shows that, compared to other technologies, it offers pedagogical added value to many subjects, contributes to the combination of formal and informal learning environments and can enhance mobile learning [3]. AR is considered as an innovating, transformative tool in education, providing students with the possibility to observe and interact with content. This integration has been proven by Dunleavy and Dede [4] to provide educationally beneficial, multimodal, contextual and interactive experiences. AR technology has been mainly researched regarding its use to enhance educational experiences, with students merely using AR tools in their daily learning practice. Nevertheless, this technology can also be looked at from a different perspective, that of students' active involvement in the creation of AR applications. In this case, the literature suggested that students developed their collaboration and communication skills by designing AR games, while in Hsu et al. [5], elementary students improved their digital literacy skills, such as information management and problem-solving, through the creation of AR artifacts.

While the literature related to the use of AR to enhance students' learning and learning experience is rather extensive, here remains a notable gap in the research concerning students' active involvement in the creation of AR applications as the number of studies examining this aspect is limited. This gap is particularly significant; through research from other areas of educational technology (e.g., game design or multimedia STEM projects), Maričić and Lavicza [6] suggest that, when students are actively engaged in creating digital tools, they develop deeper engagement with the subject matter, acquire new skills and adopt more positive attitudes towards learning.

To address this challenge, researchers are advocating for instructional methods that are practice-based and learner-centered, offering students opportunities to independently explore content and shape their own learning

outcomes. In Zapata's work [7], the Learning-By-Design Theory, according to which learners create and develop their own material, has emerged as a promising approach in this context. Research by Hutson et al. [8], as well as by Chobthamdee and Sukwan [9] has mainly highlighted the positive impact of the Learning-By-Design Theory on motivation and learning outcomes, particularly in the contexts of digital game design and video production respectively.

This doctoral colloquium paper describes the methodology for the design of research in progress. Its aim is to involve students (aged 11–12) in the two seniormost grades of primary education in the design and creation of their own AR artifacts across various subjects and to examine the effects of this involvement in learning. Specifically, the following research questions will be posed:

1) What are the students' beliefs regarding perceived ease of use, perceived usefulness, and perceived enjoyment from the design and creation process of AR artifacts?

2) What was the effect of the design and creation process of AR artifacts on students' motivation to learn?

3) What was the effect of the design and creation process of AR artifacts on students' knowledge and attitudes regarding their subjects of study?

2 Theoretical Framework

2.1 Augmented Reality and Students' learning

AR is one of the fastest-growing digital education trends in the world, encouraging both teachers and students to work in novel ways. Previous research [10] has shown that incorporating AR into the classroom improves knowledge acquisition, increases motivation and encourages self-learning; while Ke [11] adds that AR supports student interaction to bring out their creativity and make abstract concepts more tangible and engaging. It enables students to visualize and interact with complex information, such as scientific processes or historical events, in ways conventional media cannot [12]. This technology has the potential to bring about pedagogical innovations in educational settings, shifting learning from passive reception to active exploration, increasing enthusiasm for learning. Its integration into classrooms worldwide is part of a broader shift towards digital, student-centered instruction [13]. AR also supports gamified learning, where students earn rewards and complete challenges, breaking traditional learning boundaries [14]. This approach aligns with what Elford et al. [15] mention as self-determined motivation, empowering students to take ownership of their learning, being engaged at their own pace and based on their own personal interests. A key element of many of these initiatives is the promotion of student involvement in research activities, encouraging them [16], to become co-designers and co-producers of knowledge rather than mere consumers of educational products. AR is particularly well-suited to be used by learners within the context of learning by design.

2.2 Learning by Design

Learning by design is an approach that focuses on learners engaging in collaborative problem-solving within real-world design contexts [17]. It was the outcome of a collaborative effort between researchers based at the University of Illinois and RMIT University, with the support of a technical development team from Common Ground Publishing. The program is built on more than twenty years of practical and theoretical research by Kalantzis and Cope [18] and continues to build upon the theories of Multiliteracies and New Learning.

Similarly to Project-based Learning, learning by design encourages the long-term engagement with a specific topic or task. At the end of this process, a product or learning artifact is typically created, which holds significance for the learners and contributes to solving the initial problem presented. This result is then shared, discussed, and made available for public use. This approach highlights learners' role as designers, requiring them to participate in activities that involve creation and planning, addressing authentic problems that facilitate the construction of meaningful knowledge [19]. Additionally, learning by design provides a structured design process that helps learners enhance their ability to design appropriate activities; in Fleer [20], it is supported by motivating conditions and scaffolding. This framework also bridges traditional learning contexts, such as school, with the real-world, fostering soft skills like communication and project management [21].

Learning by design is often associated with the creative design of media products, as their creation involves both acquiring new knowledge and developing new skills. Numerous studies have examined, for example, how designing digital games and videos impacts learning outcomes. For instance, Hsu et al. [22] have shown that digital game design enhances mathematics learning outcomes, while Kumpulainen et al. [23] have provided evidence of its positive effect on historical learning. Regarding digital video creation, Binkley et al. [24] has reported positive effects on skills such as ICT, communication and reflection on teaching. Additionally, digital video creation has been shown to enhance writing skills [25].

The potential of the learning-by-design framework can be traced back to the core principles of constructivist and constructionist learning theories. It is more effective than conventional learning methods because it involves learners working on real-world problems in teams, allowing them to explore their own ideas and approaches, fostering higher engagement and leading to improved learning outcomes [26]. For example, Caudell and Mizell [27] have demonstrated that students' creation of course materials enhance knowledge acquisition. In addition to learning, this framework seems to have a particularly strong influence on motivational and emotional factors while learning [28]. Since no research has been conducted with this approach on students so far, this research gap has served as the motivation for the present doctoral dissertation.

3 Method

The study will use a mixed-method approach, combining both qualitative and quantitative data collection techniques to comprehensively address the research questions. The qualitative component will involve semi-structured interviews and focus groups with students engaged in designing AR applications. These tools will provide insights into student perceptions, attitudes and motivation throughout the design process, as well as explore the challenges and success they encounter with AR technology. The suggested approach will help answer the first research question: What are students' perceptions and attitudes during the design of their AR applications? The quantitative component will focus on measuring learning outcomes, specifically knowledge acquisition and motivation. By combining both methods, the study aims to gain a comprehensive understanding of how student involvement in creating AR applications impacts their learning experience.

3.1 Guided Learning by Design

The guided learning by design instructional design will consist of a number of workshops (8-10) with a duration of approximately 3 months, in which teachers will work together with students, with the latter acting as designers. Each workshop will be scheduled from 08:15 to 13:15, which is a typical primary school day in Greece. The students will design and create their own AR artifacts for the textbooks used in the subjects of History, English, and Environmental Education. These subjects were chosen based on a pilot study that was previously conducted, which showed that the students do not possess increased motivation for learning in these subjects. For this reason, user-friendly AR platforms, which do not require programming skills, but instead utilize drag and drop functionality will be used. Examples of such platforms include Zapworks (https://zap.works/) and Blippar (https://www.blippar.com/). These platforms provide the capability to augment print material with multimedia resources (e.g., images, video, sound, hyperlinks to Web 2.0 applications) and 3D objects.
The approach is based on the iterative design cycle proposed by Burghardt and Hacker [29], including the following stages:

- Clarifying design specifications and constraints
- Researching and investigating the problem/topic
- Generating alternative designs
- Choosing and justifying the optimal design
- Developing a prototype
- Testing and evaluating the design solution
- Redesigning the solution with modifications
- Communicating the achievements

3.2 Participants and Context

The study will be based on previous research on the learning-by-design framework, to examine whether young school students attending a public experimental primary school will benefit more from a guided AR learning-by-design approach. In total, 140 students, both boys and girls (aged 11–12), attending 5th to 6th Grade, will participate in the study. Learners will engage with their teachers in the different stages of the project, creating their own AR learning material, as well as identifying whether the guided AR learning-by-design approach improves learning performance.

The study extends earlier findings by Ostrow and Heffernan [30], exploring additional motivational factors, like self-efficacy, intrinsic motivation, self-determination and career motivation, as well as assessing their impact on learning performance in computer science. It emphasizes a collaborative, guided approach, involving students

and teachers working together to solve design problems, contributing to AR research by focusing on learning with media, rather than learning from media.

3.3 Case Study

Given the exploratory nature of the research and the goal to understand the in-depth experiences of students, a case study design will be used, a research strategy in which "how," "why," and "what" questions are of particular interest [31]. It will allow for an intensive examination of a specific group of primary school students who will be actively engaged in the creation of AR artifacts within a classroom context. The case study approach is particularly useful for understanding the lived experiences of students as creators of AR technology, offering, according to Ridder [32], detailed insights into both the processes and outcomes of this learning activity.

The research will be conducted in an experimental primary school; the choice of the school setting was based on criteria such as the availability of technology, teachers' willingness to incorporate AR into their curriculum and the feasibility of working with students over an extended time period. This allows for a focused examination of the intervention and its outcomes in a real educational environment.

3.4 Data Collection Tools

During the AR artifacts design process, various data collection methods will be used. First, quantitative data will be collected to measure students' motivation and beliefs. The measurement of motivation to learn will be based on the RIMMS questionnaire by Loorbach et al. [33] and IMMS by Keller [34]. They examine each of the four dimensions of the ARCS model [34-36], with three items for each. These are Attention (A), Relevance (R), Confidence (C) and Satisfaction (S). To measure students' beliefs, the variables of perceived ease of use, perceived usefulness, and perceived enjoyment from the Technology Acceptance Model (TAM) [37-38] will be used. In education, TAM has been used to examine a variety of educational contexts, including students in primary education [38-39]. Learning outcomes will be measured through pre- and post-tests assessing knowledge retention and understanding of the subject matter. Secondly, qualitative data will be collected through observation and interviews with students and teachers for the purpose of examining the learning process that was followed during the design and creation of AR artifacts by the students, as well as the factors that affected their beliefs and learning.

4 Conclusion

This doctoral colloquium paper presented the philosophy and methodology behind the design of a study that is in its initial stage and aims to involve students in the design and creation of their own AR artifacts. The study will examine the effects of the design process on students' motivation, beliefs, attitudes, and learning. The impetus for this research arose from the lack of studies in primary education focusing on the effects of students' involvement in the design of AR artifacts in subjects where they usually do not exhibit increased motivation to learn. Within this context, this study aims to focus on 140 students attending the final two grades in primary school (ages 11-12) who will be involved in the design of augmented artifacts via the Learning-By-Design Theory using easy-to-use and age-appropriate AR content design platforms. The subjects that a previous pilot study indicated would provide added value from student participation are History, English, and Environmental Education. Quantitative and qualitative data will be collected.

The results are expected to enrich the existing literature regarding the use of AR in primary education. Additionally, they are expected to have various implications both for students' learning and the use of the Learning-By-Design approach in the field of AR. In the next phase of this study, a pilot study will be designed whose objectives will be to: (1) provide a final assessment of the data collection tools, (2) conduct a small study on students for the purpose of examining all the factors that will contribute to the smooth implementation of the main study. Such factors could include the students' level of familiarity with the AR design platforms, the degree of collaboration and the type of interactions that could be developed between students, and technical issues related to the content and technical infrastructure.

References

1. Azuma, R.: A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments, 6(4), 355–385 (1997).
2. Kamińska D, Zwoliński G, Laska-Leśniewicz A, Raposo R, Vairinhos M, Pereira E, Urem F, Ljubić Hinić M, Haamer RE, Anbarjafari G.: Augmented Reality: Current and New Trends in Education. Electronics, 12, 3531 (2023).

3. FitzGerald, E., Ferguson, R., Adams, A., Gaved, M., Mor, Y., Thomas, R.: Augmented reality and mobile learning: the state of the art. International Journal of Mobile and Blended Learning, 5(4), 43–58 (2015).
4. Dunleavy, M., Dede, C. (2014): Augmented reality teaching and learning. In: Spector, J.M., Merill, M.D., Elen, J., Bishop, M.J. (eds) Handbook of research on educational communications and technology, 735–745, Springer, New York (2014).
5. Hsu, H. P., Wenting, Z., Hughes, J. E.: Developing Elementary Students' Digital Literacy Through Augmented Reality Creation: Insights From a Longitudinal Analysis of Questionnaires, Interviews, and Projects. Journal of Educational Computing Research, 57(6), 1400–1435 (2018).
6. Maričić, M., Lavicza, Z.: Enhancing student engagement through emerging technology integration in STEAM learning environments. Educ Inf Technol 29, 23361–23389 (2024).
7. Zapata, G.C.: Learning by Design and Second Language Teaching: Theory, Research, and Practice. Routledge, London & New York (2022).
8. Hutson, J., Fulcher, B., Weber, J.: Gamification in Education: A Study of Design-Based Learning in Operationalizing a Game Studio for Serious Games. Journal of Intelligent Learning Systems and Applications, 14, 115–131 (2022).
9. Chobthamdee, B., Sukwan, C.: Video Production Design by Using Project-Based Learning of Pre-Service Teachers. 2023 8th International STEM Education Conference (iSTEM-Ed 2023), 1, 1–4 (2023).
10. Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J.M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F.: Creativity, Critical Thinking, Communication, and Collaboration. Assessment, Certification, and Promotion of 21st Century Skills for the Future of Work and Education. Journal of Intelligence, 11, 54 (2023).
11. Ke, F.: An Implementation of Design-Based Learning through Creating Educational Computer Games: A Case Study on Mathematics Learning during Design and Computing. Computers & Education, 73, 26–39 (2014).
12. Wake, J.D., Guribye, F., Wasson, B.: Learning through Collaborative Design of Location-Based Games. International Journal of Computer-Supported Collaborative Learning, 13, 167–187 (2018).
13. Yeh, H.-C.; Heng, L.; Tseng, S.-S. Exploring the Impact of Video Making on Students' Writing Skills. Journal of Research on Technology in Education, 1–11 (2020).
14. Quintero, J., Baldiris, S., Cerón, J., Garzón, J., Burgos, D., Vélez, G.: Gamification as Support for Educational Inclusion.: The Case of ARmBot. 2022 International Conference on Advanced Learning Technologies (ICALT), 269–273 (2022).
15. Elford, D., Lancaster, S.J., Jones, G.A.: Fostering Motivation toward Chemistry through Augmented Reality Educational Escape Activities: A Self-Determination Theory Approach. Journal of Chemical Education, 99(10), 3406–3417 (2022).
16. Hynes, M.: Students-as-producers: Developing valuable student-centered research and learning opportunities. International Journal of Research Studies in Education, 7(4), 1–13 (2017).
17. Lin, X. F., Luo, G., Luo, S., Liu, J., Chan, K. K., Chen, H., Zhou, W., Li, Z.: Promoting pre-service teachers' learning performance and perceptions of inclusive education: An augmented reality-based training through learning by design approach. Teaching and Teacher Education, 148, 104661 (2024).
18. Kalantzis, M., Cope, B.: Learning by Design. E–Learning and Digital Media, 7(3), 198–199 (2010).
19. Van Breukelen, D., Van Meel, A., De Vries, M.: Teaching strategies to promote concept learning by design challenges. Research in Science & Technological Education, 35(3), 368–390 (2017).
20. Fleer, M.: The genesis of design: Learning about design, learning through design to learning design in play. International Journal of Technology and Design Education, 32(3), 1441–1468 (2022).
21. Buchner, J., Kerres, M.: Students as Designers of Augmented Reality: Impact on Learning and Motivation in Computer Science. Multimodal Technologies and Interaction, (8), 1–16 (2021).
22. Hsu, H. P., Wenting, Z., Hughes, J. E.: Developing Elementary Students' Digital Literacy Through Augmented Reality Creation: Insights From a Longitudinal Analysis of Questionnaires, Interviews, and Projects. Journal of Educational Computing Research, 57(6), 1400–1435 (2018).
23. Kumpulainen, K., Byman, J., Renlund, J., Wong, C.C.: Children's Augmented Storying in, with and for Nature. Education Sciences, 10(6), 149 (2020).
24. Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., Rumble, M.: Defining Twenty-First Century Skills. Assessment and Teaching of 21st Century Skills, 17–66 (2011).
25. Maričić, M., Lavicza, Z.: Enhancing student engagement through emerging technology integration in STEAM learning environments. Education and Information Technologies, 29, 23361–23389 (2024).
26. Ibrahim, E.I.M.: Mobile learning for English language learning: Benefits and challenges. European Journal of Open Education and E-learning Studies, 4(1), 44–59 (2019).
27. Caudell, T.P., Mizell, D.W.: Augmented Reality: An Application of Heads-up Display Technology to Manual Manufacturing Processes. Proceedings of the Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences; IEEE: Kauai, HI, USA, 2, 659–669 (1992).
28. Akcayir, M., Akcayir, G.: Advantages and Challenges Associated with Augmented Reality for Education: A Systematic Review of the Literature. Educational Research Review, 20, 1–11 (2017).
29. Burghardt, M.D., Hacker, M.: Informed Design: A Contemporary Approach to Design Pedagogy as the Core Process in Technology. Technology Teacher, 64, 6–8 (2004).
30. Ostrow, K.S., Heffernan, N.T.: Testing the Validity and Reliability of Intrinsic Motivation Inventory Subscales Within ASSISTments. Penstein Rosé, C., et al. Artificial Intelligence in Education. AIED 2018. Lecture Notes in Computer Science, 10947. Springer, Cham, 381–394 (2018).
31. Coombs, H. (2022). Case study research: single or multiple [White paper]. Southern Utah University (2022

32. Ridder, H. G.: The theory contribution of case study research designs. Bus Res 10, 281–305 (2017).
33. Loorbach, N., Peters, O., Karreman, J., Steehouder, M.: Validation of the instructional materials motivation survey IMMS in a self-directed instructional setting aimed at working with technology. British Journal of Educational Technology, 46(1), 204–218 (2015).
34. Keller, J. M.: Motivational design for learning and performance: The ARCS model approach. New York, Springer, 297–323 (2010).
35. Keller, J. M.: Development and use of the ARCS model of instructional design. Journal of instructional development, 10(3), 2–10 (1987).
36. Keller, J. M.: First principles of motivation to learn and e3-learning. Distance education, 29(2), 175–185 (2008).
37. Davies, F.D.: Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly 13(3), 319—339 (1989).
38. Koutromanos, G.: Understanding Primary School Students' Desire to Play Games on Smart Mobile Devices in their Leisure Time. In: Bratitsis, T. (eds) Research on E-Learning and ICT in Education, pp 39–55. Springer, Cham (2023).
39. Eskandari, S., Valente, J.P.: An Extended Technology Acceptance Model in the Context of Mobile Learning for Primary School Students. New Realities, Mobile Systems and Applications (2022).