



Improving Education With Augmented Reality: An Overview Of The Pedagogical Strategies And Game Features In Serious Games Based On Augmented Reality.

Mr. Shubham Sharma

Assistant Professor

Computer Science Department
Apex University, Jaipur, Rajasthan, India

Abstract: The potential to improve learning outcomes and increase student engagement, the combination of Augmented Reality (AR) and serious games (SGs) has drawn more attention in educational settings. Nonetheless, more thorough understanding of the particular teaching methods and components of game design that maximize the usefulness of SGs based on Augmented Reality in learning environments. The purpose of this scoping study is to classify and identify the salient characteristics of effective game elements and instructional strategies in AR-based SGs. To classify these components, a thorough multidimensional taxonomy was created. The results show that AR has a favorable impact on behavior, cognition, emotion, motivation, skills, and overall performance, among other areas of student learning. Notwithstanding these encouraging results, the review emphasizes the necessity of additional empirical research to improve and broaden the application of AR in educational games especially that which incorporates data science approaches. These observations provide insightful advice for researchers and practitioners wishing to include Augmented Reality into SGs, promoting digital education and interactive learning. The study highlights the revolutionary potential of AR in education and offers a research roadmap to optimize its effects in the future.

I. INTRODUCTION

AR creates immersive experiences by fusing virtual and real-world elements. In the field of education, its popularity is growing (Ibáñez and Delgado-Kloos, 2018). Recent advancements have increased AR's application in education by making it more accessible without requiring expensive hardware. AR has the ability to improve contextualized learning, develop cognitive abilities, and increase student engagement, especially in SGs (Manisha, Mantri, and IEEE, 2019). Use immersive and interactive activities to effectively engage students and enhance their understanding of educational concepts (Yousefi and Mirkhezri, 2019; Zaki N.A.A. Zain N.Z.M., 2020). Their instructional efficiency is increased by attributes including quick feedback and adaptable learning settings (Dele-Ajayi, Strachan, Pickard, and Sanderson, 2018). However, including successful game components and instructional techniques is crucial to AR's efficacy in SGs. Through immersive and interactive activities, SGs have been acknowledged as special teaching tools that successfully engage students and enhance their understanding of academic concepts. (Yousefi and Mirkhezri, 2019; Zaki N.A.A.Zain N.Z.M., 2020).

Their instructional efficiency is increased by attributes like quick feedback and adaptable learning settings (Dele-Ajayi et al., 2018). However, incorporating effective game features and instructional tactics is crucial to AR's efficacy in SGs. According to Fernández-Sánchez, González-Fernández, and Acevedo-Borrega (2023), emerging pedagogical methodologies place a strong emphasis on integrating digital resources to create dynamic learning experiences that enhance students' abilities, motivation, and excitement. Teachers may now

assess students' learning habits, fill in knowledge gaps, and offer specialized educational interventions thanks to game learning analytics (GLA) (Zhao, Playfoot, Nicola, Guarino, Bratu, Salvatore, and Muntean, 2022).

AR-based SGs have a lot of potential in education, but adoption is still slow. The integration of gaming components and pedagogical techniques inside AR for educational purposes is examined in this scoping review. According to Christou, Parmaxi, and Zaphiris (2024), scoping reviews are useful instruments for outlining research landscapes, spotting knowledge gaps, and offering a thorough summary of the data that is currently available. This work maps the design and implementation of AR in SGs using a methodical methodology that complies with the Joanna Briggs Institute recommendations (Peters, Godfrey, Mcinerney, and Soares, 2015). The main goal is to comprehend how AR may improve learning outcomes and successfully engage students. The purpose of this scoping review is to pinpoint the essential game components and instructional techniques that maximize AR's educational impact in SGs.

Serious games using Augmented Reality

SGs create immersive experiences that encourage motivation and active learning by fusing educational goals with captivating gaming elements. They complement learning objectives by using interactive settings and structured rules, giving students special chances to experiment, explore, and learn via active engagement (Yousefi and Mirkhezri, 2019; Fernández-Sánchez et al., 2023). However, in order to guarantee that cognitive resources are allocated towards learning rather than navigating the gaming interface, its efficacy depends on combining good pedagogical concepts with usability-focused design (Kreutzer, Marks, and Bowers, 2015).

By providing instant feedback, encouraging behavioral changes, and accommodating a variety of learning contexts, research shows that SGs have the ability to improve the educational experience (Yousefi and Mirkhezri, 2019). Notwithstanding these advantages, adoption in formal education is still restricted because of issues like teachers' resistance to implementing new technology and a vague awareness of the benefits that SGs offer in the classroom (Calvo-Morata, Alonso-Fernandez, Freire-Moran, Martinez-Ortiz, and Fernandez-Manjon, 2019). Therefore, cooperation between educators and designers is necessary for effective SG design in order to match instructional materials with game dynamics, promoting participation and significant learning.

The integration of the digital and physical worlds through AR produces immersive and instructive interactive experiences that improve SGs (Li, Van Der Spek, Hu, and Feijs, 2022). AR-enabled SGs promote deeper comprehension and engagement by enabling students to manipulate and visualize difficult ideas. AR is very useful for education since it allows for the investigation of abstract concepts, spatial reasoning, and temporal understanding by superimposing digital elements onto real-world situations (Koutromanos, Sofos, and Avraamidou, 2015).

By adding collaborative components and gamified features like levels, badges, and leaderboards to encourage learners, AR also solves drawbacks of traditional SGs, like the absence of social contact (Li et al., 2022). Additionally, by enabling real-time competition and prizes, AR promotes both internal and extrinsic motivation, all of which are essential for sustaining student interest and engagement. Developing interesting and relevant tasks that spark students' attention, align with their passions, and promote problem-solving skills is essential to fostering intrinsic motivation in the classroom. Conversely, extrinsic motivation can be a useful instrument for promoting engagement, especially when paired with strategies that cultivate an innate, intrinsic desire to learn.

Research continuously demonstrates that AR in SGs, particularly in educational contexts, enhances learning results, motivation, and satisfaction for teachers and students (Ferner, Perdomo, Rashed-Ali, Fies, and Quarles, 2013; Li et al., 2022). Nevertheless, there are still obstacles to overcome in the creation and application of AR-based SGs, namely in relation to budgetary limitations and the difficulty of incorporating game learning analytics (GLA) into educational frameworks (Freire, Calvo-Morata, Martinez-Ortiz, and Fernandez-Manjon, 2023). To fully realise AR's promise to improve the educational experience, these obstacles must be removed.

With its unparalleled blend of digital involvement and real-world context, Augmented Reality (AR) has become a disruptive tool in the social game space (Arici, Yildirim, Caliklar, and Yilmaz, 2019; Gao, Lu, Ooi, Cai, and Gunawan, 2023). By overlaying digital elements onto the real world, Augmented Reality (AR)

enhances the immersive quality of educational games and makes learning more dynamic, interactive, and captivating (Tene, Marcatoma Tixi, Palacios Robalino, Mendoza Salazar, Vacacela Gomez, and Bellucci, 2024).

By promoting active participation, AR in SGs improves engagement (Bakhtiari, Seraji, Farrokhnia, Habibzadeh, and Noroozi, 2024). AR games accommodate a range of learning styles by engaging students through visual, aural, and kinaesthetic interactions, in contrast to traditional teaching methods (Lin et al., 2024) for instance, students can interact with 3D models of complex subjects like geometric forms in mathematics or molecules in chemistry, which helps them understand abstract ideas more clearly (Christian Moro, Zane Tromberga, Athanasios Raikos, and Allan Stirling, 2017). Additionally, by letting users solve problems in a realistic yet simulated setting, Augmented Reality promotes exploratory learning (Wu, Lee, Chang, and Liang, 2013)

In addition to keeping students interested, this experiential method improves comprehension and memory of the material (Li et al., 2024). By transforming boring subjects into exciting excursions, location-based assignments and gamified rewards boost motivation (Yilmaz & Goktas, 2017). The ability of AR to customize learning experiences is a significant additional feature in SGs. Information can be tailored via adaptive AR systems to the learner's choices, pace, and advancement, guaranteeing sustained involvement while lowering annoyance (Arici et al., 2019). By fostering curiosity and a desire to solve problems, this kind of personalization promotes internal motivation in addition to external incentive through rewards and progression mechanisms (Arici et al., 2019). Additionally, AR helps close the knowledge gap between theory and practice, particularly in the field of education (Christian Moro et al., 2017). Students can foster creativity and critical thinking by applying theoretical knowledge to real-world problems and simulating real-world situations (Tene et al., 2024). This practical approach aligns with contemporary educational objectives of equipping learners for real-world scenarios (Bakhtiari et al., 2024).

In conclusion, the combination of AR and SGs offers a revolutionary approach to education by providing fresh approaches to student engagement, knowledge gap filling, and the development of 21st century skills. Teachers and game designers may produce memorable learning experiences that are suited to a range of educational needs by utilizing AR's immersive and interactive features.

II. LITERATURE REVIEW

The goal of this project is to study the integration of AR in SGs for education through a thorough scoping review. Our specific goal is to find pedagogical strategies and gaming aspects in AR-based SGs that improve learning results. In order to do this, the study will create a multifaceted taxonomy that classifies important components of AR-based SGs with an emphasis on how they affect students' behavior, motivation, abilities, and cognition. By offering useful advice to academics, educators, and developers working on the creation and deployment of AR-based SGs, this paper seeks to close knowledge gaps on AR's potential in education. This scoping review tackles the following general questions in order to assess, compile, and critically analyze the empirical evidence currently available on the usage of AR in SGs for education: Question for Research (RQ) .To what extent do AR-based SGs improve and involve students in learning? Table 1 contains particular sub-questions that further investigate this main RQ.

Table 1: Question for Research (RQ)

| ID | Research Question |
|-----|--|
| RQ1 | What game elements are essential for engaging students in education when using AR in SGs? |
| RQ2 | What pedagogical approaches have been found to be affective for engaging students in education through AR in SGs? |
| RQ3 | How do the essential game elements and pedagogical approaches identified in the literature differ across different education disciplines and grade levels. |

III. RESOURCE AND TECHNIQUES

Eligibility criteria and search phrases were used in the first literature search and article selection procedure. Evaluation, eligibility assessment, and article retrieval took place between 2012 and 2024. We took the following steps in accordance with the protocol for this review. Prior to conducting the research, the research objectives and search phrases must be established. We next looked at articles using inclusion and exclusion criteria before summarizing and presenting the salient characteristics and important discoveries of the included research.

3.1 Data Archives

We looked through several important databases, including Web of Science, Scopus, IEEE Xplore, ScienceDirect, and SpringerNature, to make sure the review was thorough. In order to expand the search across fields and geographical areas, we also included resources like ERIC, PubMed, and ProQuest. This strategy sought to document a range of viewpoints regarding AR-SGs and their uses in different cultural and educational contexts. In order to find more papers that satisfied our inclusion criteria, we also looked through the reference lists of pertinent articles, including systematic reviews and meta-analyses.

3.2 Research Methodology

The CiteSpace tool, was used to extract the data. The increasing interest in employing SGs for educational purposes is demonstrated by the 178 articles that our search terms produced, as indicated in Table 2. In order to engage students in education through AR-based SGs, only 58 papers were considered significant for this literature analysis. The most publications were found in the Web of Science, which was followed by IEEE Xplore, ScienceDirect, Springer, and Scopus. The titles and abstracts of every paper were reviewed in accordance with the inclusion and exclusion criteria. If the eligibility requirements were met, the entire text would be extracted.

Table 2: Eligibility criteria for inclusion in scoping review

| Inclusion Criteria | Exclusion Criteria |
|--|--|
| Accept studies published in English between 2010 and 2024 to account for technological advancements. | The article is not in the English language. |
| Include studies from all educational levels (Primary, secondary, and tertiary) and across various disciplines. | Articles whose full text is not available online. |
| Consider works focusing on AR and other educational technologies in the context of engagement, | The article discusses aspects not in relation to our research topic. |

| Inclusion Criteria | Exclusion Criteria |
|-----------------------------------|--------------------|
| pedagogy, and learning analytics. | |

A wide range of expressions (phrases and operators) commonly employed in systematic literature reviews were used to combine these search terms. This stage involved searching the full text, abstract, and title of articles to find them. The following search phrases were used to conduct the entire review: "serious game" or "educational game" or "Augmented Reality" or "virtual reality" or "AI in education" or "technology enhanced learning" or "teaching with gamification." This more comprehensive set of search terms sought to find research investigating new technologies like as VR and AI in addition to AR in SGs, allowing for a comparative evaluation of their potential for education.

To guarantee eligibility and inclusion, the returned articles were examined. To find further articles to include, each item's reference list was examined. The extra papers were reviewed for inclusion.

3.3 Result Discussion

Through a scoping examination of 178 studies, 58 of which met the inclusion criteria, this study examines the usage of AR in SGs for education. Our results demonstrate how AR-SGs have a great deal of promise to improve learning outcomes and student engagement in a variety of academic fields. Finding essential game components and instructional strategies that successfully apply AR in SGs is the main objective. AR-SGs establish a dynamic learning environment where students learn through interactive play by putting teachers in the role of game designers. In order to provide insights for creating successful educational games and evaluating user experience, the review looks at how learning measures, game design, and educational outcomes interact. In this paper we are going to present various analysis performed using CiteSpace.

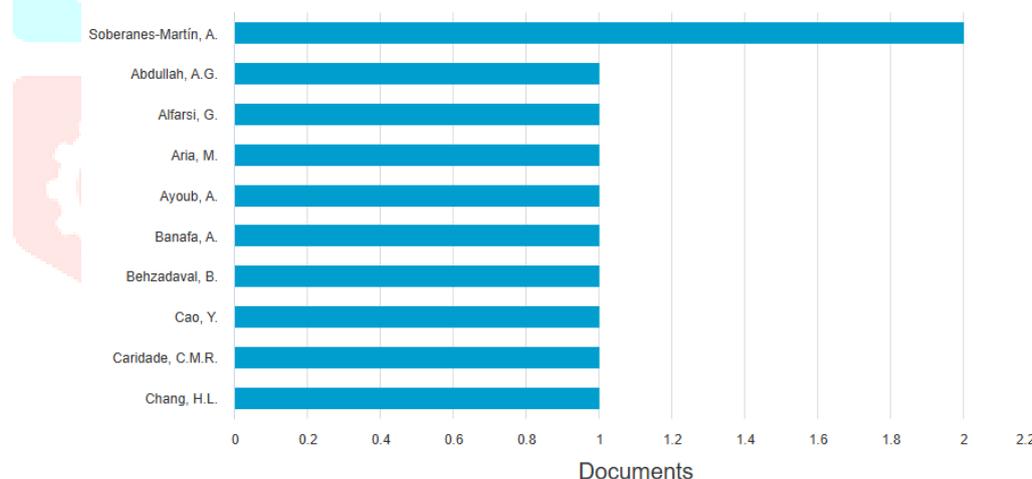


Figure 1: Document count of top 15 authors

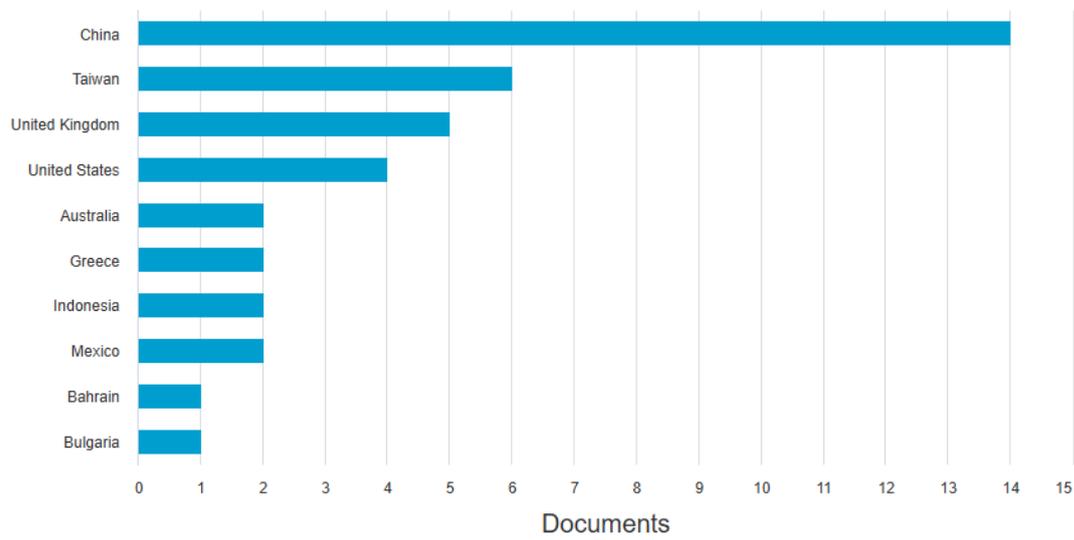


Figure 2: Document count of top 15 countries

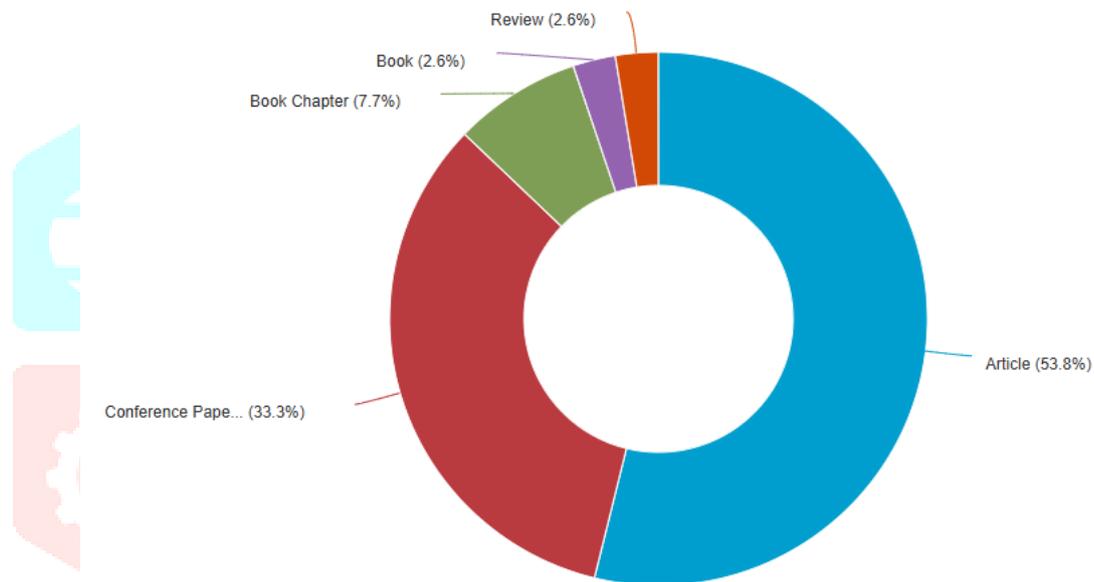


Figure 3: Analysis of Scopus based papers for AR in SG.

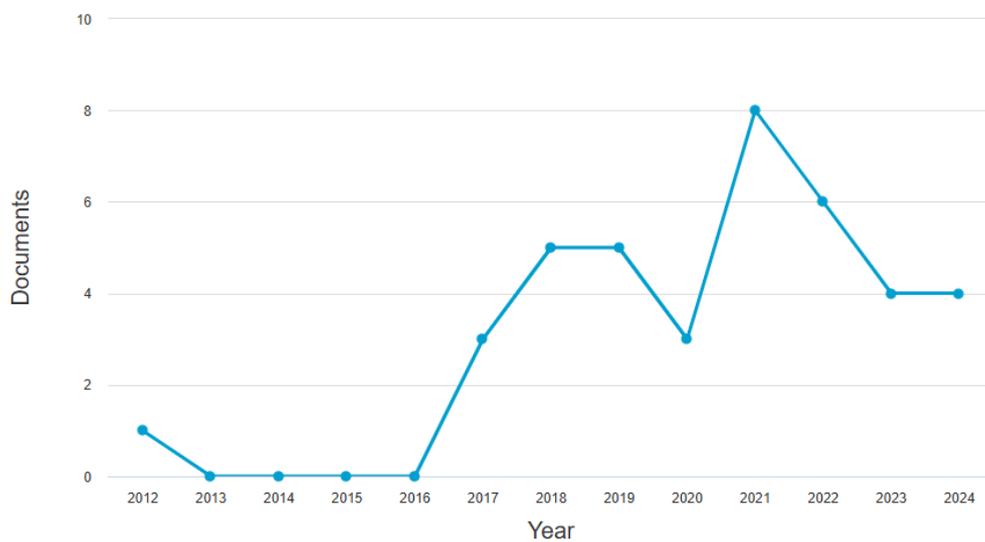


Figure 4: Year wise analysis of AR in SG Documents.

IV. CONCLUSION

The revolutionary potential of Augmented Reality-based serious games (AR-SGs) in changing the educational landscape is highlighted in this study. ARSGs provide a dynamic and captivating learning environment that fosters cognitive, social, and emotional growth by skillfully fusing immersive game components with strong pedagogical techniques. Successful game design must be in line with specific learning goals, inclusive and accessible for a wide range of learners, and usability issues must be resolved to produce a simple and efficient user experience.

REFERENCES

- [1] Arici, F., Yildirim, P., Caliklar, , Yilmaz, R.M., 2019. Research trends in the use of Augmented Reality in science education: Content and bibliometric mapping analysis. *Computers and Education* 142. doi:10.1016/j.compedu.2019.103647.
- [2] Baaden, M., Delalande, O., Ferey, N., Pasquali, S., Waldispühl, J., Taly, A., 2018. Ten simple rules to create a serious game, illustrated with examples from structural biology. doi:10.1371/journal.pcbi.1005955.
- [3] Bakhtiari, R., Seraji, F., Farrokhnia, M., Habibzadeh, Z., Noroozi, O., 2024. Games in education: a systematic review of studies in international and Iranian contexts. *Educational technology research and development* URL: <https://doi.org/10.1007/s11423-024-10426-1>, doi:10.1007/ s11423-024-10426-1.
- [4] Calvo-Morata, A., Alonso-Fernandez, C., Freire-Moran, M., MartinezOrtiz, I., Fernandez-Manjon, B., 2019. Game Learning Analytics, Facilitating the Use of Serious Games in the Class. *Revista Iberoamericana de Tecnologías del Aprendizaje* 14, 168–176. doi:10.1109/RITA.2019. 2952296.
- [5] Carvalho, M.B., Bellotti, F., Berta, R., De Gloria, A., Gazzarata, G., Hu, J., Kickmeier-Rust, M., 2015. A case study on Service-Oriented Architecture for Serious Games. *Entertainment Computing* 6, 1–10. doi:10.1016/j.entcom.2014.11.001.
- [6] Christian Moro, Zane Štromberga, Athanasios Raikos, Allan Stirling, 2017. Theeffectiveness of virtual and Augmented Reality in health sciences and medical anatomy. *Anatomical sciences education* 10, 549–559.
- [7] Christou, E., Parmaxi, A., Zaphiris, P., 2024. A systematic exploration of scoping and mapping literature reviews. *Universal Access in the Information Society* doi:10.1007/s10209-024-01120-3.
- [8] Costa M.C. Vital F.M., M.A.P.J.S.P.R.G.M.M.A.B.M., 2020. An augmentedrealityinformationsystemdesignedtopromoteSTEMeducation 2733. De Oliveira, F.S., Santos, S., 2016.
- [9] PBLMaestro: A virtual learning environment for the implementation of problem-based learning approach in Computer education, in: *Proceedings- Frontiers in Education Conference, FIE, Institute of Electrical and Electronics Engineers Inc.* doi:10.1109/FIE.2016.7757388.
- [10] De Troyer, O., Janssens, E., 2014. Supporting the requirement analysis phase for the development of serious games for children. *International Journal of Child-Computer Interaction* 2, 76–84. doi:10.1016/j.ijcci. 2014.05.001.
- [11] Dele-Ajayi, O., Strachan, R., Pickard, A., Sanderson, J., 2015. Girls and science education: Exploring female interests towards learning with Serious Games: A study of KS3 girls in the North East of England, in: *Proceedings of 2015 International Conference on Interactive Mobile Communication Technologies and Learning, IMCL 2015, Institute of Electrical and Electronics Engineers Inc.*. pp. 364–367. doi:10.1109/ IMCTL.2015.7359620.
- [12] Dele-Ajayi, O., Strachan, R., Pickard, A., Sanderson, J., 2018. Designing for All: Exploring Gender Diversity and Engagement with Digital Educational Games by Young People. 2018 *IEEE Frontiers in Education Conference (FIE)*, 1–9doi:10.1109/FIE.2018.8658553.
- [13] Fernández-Sánchez, M.R., González-Fernández, A., Acevedo-Borrega, J., 2023. Conceptual Approach to the Pedagogy of Serious Games. *Information (Switzerland)* 14. doi:10.3390/info14020132.
- [14] Ferrer, V., Perdomo, A., Rashed-Ali, H., Fies, C., Quarles, J., 2013. How does usability impact motivation in Augmented Reality serious games for education?, in: *2013 5th International Conference on Games and Virtual Worlds for Serious Applications, VS-GAMES 2013.* doi:10. 1109/VS-GAMES.2013.6624233.

- [15] Freire, M., Calvo-Morata, A., Martinez-Ortiz, I., Fernandez-Manjon, B., 2023. Bootstrapping serious games to assess learning through analytics, in: IEEE Global Engineering Education Conference, EDUCON, IEEE Computer Society. doi:10.1109/EDUCON54358.2023.10125177.
- [16] Gao, S., Lu, Y., Ooi, C.H., Cai, Y., Gunawan, P., 2023. Designing interactive Augmented Reality application for student's directed learning of continuous distillation process. *Computers and Chemical Engineering* 169. doi:10.1016/j.compchemeng.2022.108086.
- [17] Hanus, M.D., Fox, J., 2015. Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers and Education* 80, 152–161. doi:10.1016/j.compedu.2014.08.019.
- [18] Ibáñez, M.B., Delgado-Kloos, C., 2018. Augmented Reality for STEM learning: A systematic review. *Computers & Education* 123, 109123. URL: <https://www.sciencedirect.com/science/article/pii/S0360131518301027>, doi:<https://doi.org/10.1016/j.compedu.2018.05.002>.
- [19] Koutromanos, G., Sofos, A., Avraamidou, L., 2015. The use of Augmented Reality games in education: a review of the literature. *Educational Media International* 52, 253–271. doi:10.1080/09523987.2015.1125988.
- [20] Kreutzer, C., Marks, M., Bowers, C., 2015. A pedagogical approach to usability in serious games, in: *Communications in Computer and Information Science*, Springer Verlag. pp. 43–48. doi:10.1007/978-3-319-21380-4_{\ }8.
- [21] Kuo, M.S., Chuang, T.Y., 2016. How gamification motivates visits and engagement for online academic dissemination- An empirical study. *Computers in Human Behavior* 55, 16–27. doi:10.1016/j.chb.2015.08.025.
- [22] Leao, C.P., Soares, F., Carvalho, V., Lopes, S., Goncalves, I., 2017. A Serious Game Concept to Enhance Students' Learning of Statistics. *PROCEEDINGS OF 2017 4TH EXPERIMENT@INTERNATIONAL CONFERENCE(EXP.AT'17)*, 187–190. Li, J., Van Der Spek, E., Hu, J., Feijs, L., 2022. Extracting Design Guidelines for Augmented Reality Serious Games for Children. *IEEE Access* 10, 66660–66671. doi:10.1109/ACCESS.2022.3184775.
- [23] Manisha, Mantri, A., IEEE, 2019. An Augmented Reality Application for Basic Mathematics: Teaching and Assessing Kids' Learning Efficiency. *2019 5TH INTERNATIONAL CONFERENCE ON COMPUTING, COMMUNICATION, CONTROL AND AUTOMATION (ICCUBEA)*.
- [24] Munsinger, B., White, G., Quarles, J., 2019. The Usability of the Microsoft HoloLens for an Augmented Reality Game to Teach Elementary School Children. *2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)*, 1–4. doi:10.1109/VS-Games.2019.8864548.
- [25] Nagalingam, V., Ibrahim, R., 2015. User Experience of Educational Games: A Review of the Elements, in: *Procedia Computer Science*, Elsevier B.V.. pp. 423–433. doi:10.1016/j.procs.2015.12.123. Peters, M., Godfrey, C.M., McInerney, P., Soares, C.B., 2015.
- [26] Methodology for JBI Scoping Reviews. Technical Report. URL: <https://www.researchgate.net/publication/294736492>. Pittman, C., LaViola, J.J., 2019. Determining Design Requirements for AR Physics Education Applications. *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, 1126–1127. doi:10.1109/VR.2019.8797908.
- [27] Simões, J., Redondo, R.D., Vilas, A.F., 2013. A social gamification framework for a K-6 learning platform. *Computers in Human Behavior* 29, 345–353. doi:10.1016/j.chb.2012.06.007.
- [28] Smith, K., Shen, Y., Shull, J., Dean, T., Michaeli, J., 2016. A toolkit for presenting advanced mathematics in serious games, in: *SoutheastCon*.
- [29] Sureephong, P., Puritat, K., Chernbumroong, S., 2017. Enhancing user performance and engagement through gamification: Case study of aqua republica, in: *SKIMA 2016- 2016 10th International Conference on Software, Knowledge, Information Management and Applications*, Institute of Electrical and Electronics Engineers Inc.. pp. 220–224. doi:10.1109/SKIMA.2016.7916223.
- [30] Tene, T., Marcatoma Tixi, J.A., Palacios Robalino, M.d.L., Mendoza Salazar, M.J., Vacacela Gomez, C., Bellucci, S., 2024. Integrating immersive technologies with STEM education: a systematic review. doi:10.3389/feduc.2024.1410163.
- [31] Terzidou, T., Tsiatsos, T., Miliou, C., Sourvinou, A., 2016. Agent Supported Serious Game Environment. *IEEE Transactions on Learning Technologies* 9, 217–230. doi:10.1109/TLT.2016.2521649.

- [32] Uskov, V.L., Bakken, J.P., Aluri, L., 2019. Crowdsourcing-Based Learning: the Effective Smart Pedagogy for STEM Education. PROCEEDINGS OF 2019 IEEE GLOBAL ENGINEERING EDUCATION CONFERENCE(EDUCON),1552–1558.
- [33] Van Eck, R., Guy, M., Young, T., Winger, A., Brewster, S., 2014. Project NEO: Assessing and changing preservice teacher science knowledge withavideogame,in:Proceedings-IEEE14thInternationalConference on Advanced Learning Technologies, ICALT 2014, Institute of Electrical and Electronics Engineers Inc.. pp. 339–343. doi:10.1109/ICALT. 2014.102.
- [34] Wei, X., Xi, P., 2022. The Golden Ratio of Instructive Content to Entertaining Content in Mobile Augmented Reality Games. 2022 International Symposium on Educational Technology (ISET) , 189–191doi:10.1109/ ISET55194.2022.00048.
- [35] Wu, H.K., Lee, S.W.Y., Chang, H.Y., Liang, J.C., 2013. Current status, opportunities and challenges of Augmented Reality in education. Computers and Education 62, 41–49. doi:10.1016/j.compedu.2012.10.024.
- [36] Yilmaz, R., Goktas, Y., 2017. Using Augmented Reality technology in storytelling activities: examining elementary students' narrative skill and creativity. Virtual Reality 21. doi:10.1007/s10055-016-0300-1.
- [37] Yousefi, B.H., Mirkhezri, H., 2019. Toward A Game-based Learning Platform : A Comparative Conceptual Framework for Serious Games, in: Proceedings of the 2019 International Serious Games Symposium, ISGS 2019, Institute of Electrical and Electronics Engineers Inc.. pp. 74–80. doi:10.1109/ISGS49501.2019.9046979.
- [38] Zaki N.A.A. Zain N.Z.M., N.N.H.H., 2020. Developing a conceptual model of learning analytics in serious games for stem education 9. doi:10.15294/jpii.v9i3.24466.
- [39] Zhao, D., Playfoot, J., Nicola, C.D., Guarino, G., Bratu, M., Salvadore, F.D., Muntean, G.M., 2022. An Innovative Multi-Layer Gamification Framework for Improved STEM Learning Experience. IEEE Access 10, 3879–3889. doi:10.1109/ACCESS.2021.3139729.

