

Blending culture and technology: Developing AR ethnomathematics media for flat-sided solid figures learning material

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KEYWORDS

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ABSTRACT The integration of Augmented Reality (AR) within educational frameworks shows significant promise in enhancing learning outcomes. This study developed an AR tool incorporating ethnomathematical approaches to aid eighth-grade students at SMP/MTs in understanding flat-sided solid figures. Grounded in ethnomathematical principles, the tool was designed to merge real and virtual worlds, presenting interactive elements in real-time to enrich the learning experience. A rigorous evaluation by six experts assessed the tool's educational viability and alignment with the curriculum, while pilot studies on its efficacy and appeal were conducted in two phases: a preliminary trial with 10 students and a broader evaluation with 32 students at MTs Negeri 2 Bandar Lampung. The evaluations underscored the tool's suitability for educational use, with validation scores indicating strong content relevance and technical functionality. Both trials demonstrated high engagement levels, with average attractiveness scores of 3.62 and 3.7, respectively, highlighting its appeal. The research concludes that the AR tool, through its integration of cultural insights and innovative technology, not only captivates but also significantly enhances the educational experience for students, fostering a deeper understanding of mathematical concepts. This validates the potential of AR in educational settings, particularly when combined with ethnomathematical elements to create a more engaging and effective learning environment.

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1. INTRODUCTION

In the digital age, mathematics education faces significant challenges in conveying abstract concepts, especially those related to flat-sided solid figures (Çevikbaş et al., 2023; Molina-Toro et al., 2019). According to Borba et al. (2016) and Gravemeijer et al. (2017), traditional teaching methods widely implemented in schools are often less effective in facilitating students' deep understanding of complex mathematical concepts. They discovered that conventional approaches frequently fail to connect material with students' real-life experiences, which is crucial for building conceptual understanding. This underscores the importance of innovating teaching strategies to enhance student engagement and comprehension. Heryanto et al. (2023) and Rullis & Fauzan (2021) argue that the lack of effective visualization and interactivity in mathematics learning contributes to students' difficulties in internalizing concepts of flat-sided solid figures. They contend that leveraging technology, such as Augmented Reality (AR), can provide richer visual representations and direct interaction with the material, significantly enhancing student understanding. This highlights the need to integrate innovative technological solutions into the mathematics curriculum.

In addressing the difficulties students face in understanding abstract mathematical concepts, this research proposes the integration of Augmented Reality (AR) technology with an ethnomathematical approach. AR, with its ability to interactively blend elements of the real world with digital information, promises an improvement in the visualization of learning materials (Afnan et al., 2021; Poerwanti et al., 2019). AR has shown the potential to enhance student understanding through more immersive and interactive learning experiences (Freitas et al., 2009). This technology enables students to explore geometric concepts in three dimensions, enriching their learning experience in ways traditional methods cannot offer. Additionally, the ethnomathematical approach provides a relevant and engaging context for students by associating learning materials with local culture local (Andriani et al., 2020; Rodríguez-Nieto & Pastells, 2022). A study by Gay (2002) found that students exhibit increased interest and understanding in mathematics when taught through the lens of their own culture. This approach helps students grasp the application of mathematics in everyday life and strengthens the connection between mathematical learning and the real world. The integration of AR and ethnomathematics is expected to offer an innovative solution for mathematics learning. The use of AR can enhance the visualization and understanding

of abstract concepts, while ethnomathematics adds contextual and cultural value. The combination of these two approaches is anticipated to potentially create a more comprehensive and engaging learning experience.

Numerous studies have explored the integration of Augmented Reality (AR) with ethnomathematical approaches, focusing on diverse cultural contexts (Abdullah et al., 2022; Muwahiddah et al., 2021; Richardo et al., 2023; Rino et al., 2023; Rochmadi et al., 2023; Sudirman et al., 2020; Sultan, 2023). These investigations have predominantly applied the unique cultural aspects of their respective regions. However, an exploration within the Lampung region's context remains absent. The rich culture of Lampung, intertwined with mathematical concepts, presents a promising avenue to simplify and enhance the learning experience of mathematics for students in Lampung. Addressing this research gap, this study aims to develop an Augmented Reality Media grounded in ethnomathematical approaches, specifically designed to enhance students' understanding of flat-sided solid figures.

2. METHOD

2.1 Research Design

This study employs a Research and Development (R&D) approach, utilizing the ADDIE model, which encompasses the stages of Analysis, Design, Development, Implementation, and Evaluation. This methodology is chosen for its systematic process of designing and evaluating educational interventions, allowing for iterative refinements. The initial Analysis phase involves identifying the learning needs, understanding learner characteristics, and reviewing the current curriculum. During the Design phase, the conceptual framework for the Augmented Reality (AR) application is established, including the creation of use cases, flowcharts, and marker card designs. The Development stage involves crafting the application using Unity 3D and Vuforia SDK, integrating 3D objects, 2D elements, and programming scripts. Implementation involves field-testing with targeted learners, and the Evaluation phase assesses the effectiveness and suitability of the AR application through formative and summative assessments.

2.2 Participants

The participants of this study are eighth-grade students at MTs Negeri 2 Bandar Lampung, selected for their relevance to the educational content being developed. The choice of this group is strategic, aiming to directly assess the impact of the AR application on learning outcomes within the intended demographic. A total of 32 students participate in the study, ensuring a diverse representation of learner interactions with the AR tool. The selection criteria are based on availability and willingness to engage with the new learning medium, ensuring ethical considerations and consent are prioritarily addressed. This participant group provides valuable insights into the applicability and effectiveness of the AR application in real educational settings.

2.3 Research Instruments

The instruments utilized in this research include expert questionnaires, learner feedback surveys, and performance assessments. Expert questionnaires are designed to evaluate the content validity and pedagogical soundness of the

AR application, engaging both subject matter and educational technology experts. Learner feedback surveys are administered post-interaction, focusing on usability, engagement, and perceived learning enhancement. Performance assessments, structured around the educational objectives of the AR application, measure the actual learning outcomes against predefined benchmarks. These instruments are crucial for gathering comprehensive data on the effectiveness, usability, and educational value of the AR tool.

2.4 Data Analysis

Data collected through expert evaluations, learner surveys, and performance tests are subjected to rigorous analysis to determine the efficacy of the AR application. Expert feedback is analyzed using qualitative thematic analysis to identify common themes and suggestions for improvement. Learner surveys are statistically analyzed to quantify user satisfaction, engagement levels, and perceived learning gains. Performance data are compared pre- and post-application use to objectively assess learning outcome improvements. The triangulation of these data sources provides a robust framework for evaluating the AR application's impact on learning, ensuring any conclusions drawn are well-supported by evidence.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 AR Design Architecture and Implementation

In the application design phase, the system architecture was conceptualized using a Use Case Diagram. The Use Case Diagram serves as a fundamental tool to outline the system's objectives, depicting the sequence of activities and user interactions necessary to fulfill those objectives.

Use Case of the Augmented Reality Application, elucidating the expected functionalities within the system. This depiction serves to outline interactions between the user (actor) and the system, highlighting a user interface that offers selections from a menu including Instructions, Basic Competencies, Material, AR Scan, Exercises, and Profile. Specifically, within the AR Scan menu, users have the option to view 3D representations of flat-sided solid figures. Upon selecting the AR Scan option and positioning the camera over a marker, the system attempts to detect the marker. If the marker is recognized as valid, a 3D animation corresponding to the marker will be displayed. Conversely, if the marker is not validated, the 3D animation will not be generated, indicating a seamless integration between physical markers and digital content in facilitating an interactive learning experience.

Flowchart or storyboard that outlines the design process for the learning media. This step is crucial as it allows the researcher to meticulously plan the user interface of the educational media, ensuring that it is user-friendly and intuitive. The design phase is instrumental in determining the visual and interactive elements that will be presented to the users of the learning media, aiming to enhance the educational experience by making the content accessible and engaging. This strategic planning phase is essential for aligning the application's functionalities with educational goals, thereby optimizing the learning journey for the users

The research results, as delineated from the flowchart, are detailed as follows: Initially, users will activate the learning media, which introduces an opening screen or an option to click 'start,' leading to the main menu. The main menu displays various buttons, including instructions, core and basic competencies (KI/KD), materials, evaluation, AR Scan, and profile. The 'Instructions' button reveals how to utilize the learning media effectively. The 'KI/KD' button presents details on Core Competencies, Basic Competencies, and Competency Achievement Indicators. Accessing the 'Materials' button unveils discussions on subtopics. The 'Evaluation' button offers 10 essay questions for the user to complete, with scores provided upon completion. The 'AR Scan' button activates the camera in AR mode to read available markers. The 'Profile' button provides information about the learning media's creators. Each menu includes a button to return to the main menu. A red 'X' button serves as the option to exit the application.

The learning media was successfully developed using Unity software version 5.6.1f1, supplemented by other software tools such as Photoshop and Blender 3D for design and development. The opening screen of the learning media, which appears upon startup, features the logo of the Universitas Islam Negeri Raden Intan Lampung, followed by the transition to the main content.

The user will be directed to press the start button to open the learning media which will display the main menu display in Figure 1(A).

Figure 1(C) displays the main menu interface of the application, featuring navigation buttons designed to facilitate scene transitions. Within this scene, several key buttons are present: the 'Instructions' button reveals a pop-up with guidance on how to use the application; the 'KI/KD/IPK' button unveils pop-ups detailing relevant curriculum components aligned with the material; and the 'Material' button opens pop-ups containing content on cubes, blocks, prisms, and pyramids. The 'Scan AR' button directs users to an Augmented Reality scene focusing on flat-sided solid figures. Additionally, the 'Evaluation' button leads to a question menu scene, while the 'Profile' button provides pop-up information about the application's creators. A distinct red 'X' button offers users the option to exit the application. The material menu itself is subdivided into four key topics for exploration: cubes, blocks, prisms, and pyramids, each providing a focused discussion on the respective subject matter.

The next stage is to scan the spatial marker image. The scan results will show an explanation of the tourist attraction, 3D rotation and characteristics that can be clicked on the explanation button as in Figure 1(F).

Figure 1(F) illustrates the functionality of the Augmented Reality (AR) scan. When activated, it engages the AR camera, which is programmed to recognize predefined markers. Upon detecting a marker, the system generates a three-dimensional representation of the geometric shape under examination, seamlessly integrating digital objects into the user's physical environment. This feature enhances the interactive learning experience by providing a tangible connection between theoretical concepts and visual representation.

The evaluation menu is designed to consolidate the user's knowledge acquired from the educational content. It comprises ten essay-type questions that challenge the user to apply the concepts learned through the AR medium.

Upon completion of these questions, the system calculates and displays the user's score, offering immediate feedback on their understanding and mastery of the material. This assessment mechanism is crucial for reinforcing learning and identifying areas where further study may be required.

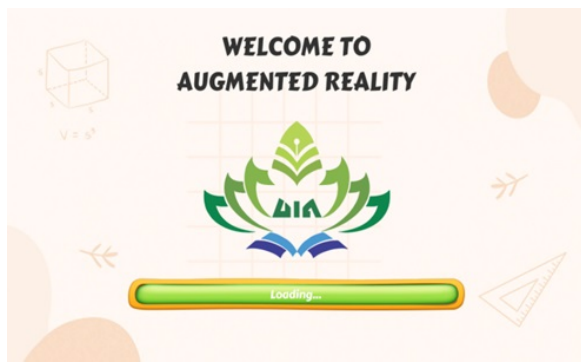
Upon completing the design phase, the research proceeded with validation by media and subject matter experts, conducted by professors from the Mathematics Education department at UIN Raden Intan Lampung. Feedback from these experts yielded several constructive suggestions for improvement, including: 1) Expansion of the discussion within the material to provide deeper insights. 2) Inclusion of additional example problems to enhance comprehension. 3) Incorporation of evaluation questions to facilitate assessment of understanding. 4) Addition of corner points in the AR scan feature for improved interactivity. 5) Refinements to the creator profile to ensure accuracy and professionalism.

Following these expert recommendations, the research team implemented the suggested enhancements. A preliminary trial was then conducted with a small group of ten eighth-grade students from MTs Negeri 2 Bandar Lampung, Class VIII I, to gauge initial responses and effectiveness. Encouraged by the outcomes of this pilot study, a larger-scale trial was subsequently undertaken involving all 32 students from the same class. After this comprehensive testing, students were asked to complete a survey to capture their feedback on the learning media.

The final phase of this development model is the evaluation stage, where the research team conducted an in-depth analysis of the collected data, focusing on the validity of the media and materials as assessed by six experts, along with analyzing the responses from student surveys. Following the revision of the product based on feedback and critiques from several validators, the revised product was pilot-tested. The feedback from both teachers and students indicated that the developed product was of high quality and deemed suitable for use, being rated as "Very Attractive." This feedback leads to the conclusion that the development of an Augmented Reality-based learning media, incorporating an ethnomathematical approach for the topic of flat-sided solid figures, has been successfully completed and is ready for implementation in educational settings.

3.1.2 User Study

The development of the Augmented Reality (AR)-based learning media was conducted to assess its feasibility and appeal as determined by the research. Validation data was collected from six experts, encompassing media and subject matter specialists, alongside surveys administered to students. The attractiveness of the product was gauged through student response surveys, which, in a preliminary small-scale trial, yielded an average score of 3.62, categorizing the media as "Very Attractive". In a subsequent larger-scale trial, the media achieved an average score of 3.7, maintaining its "Very Attractive" rating. These outcomes suggest that the AR learning media, designed with an ethnomathematical approach for teaching flat-sided solid figures, successfully meets the criteria for appeal. Consequently, it is deemed suitable for implementation, indicating that the developed AR learning media not only engages students effectively but also holds significant educational value in enhancing the learning experience.



(A)



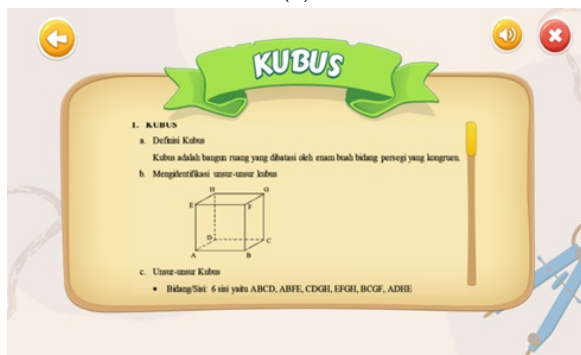
(B)



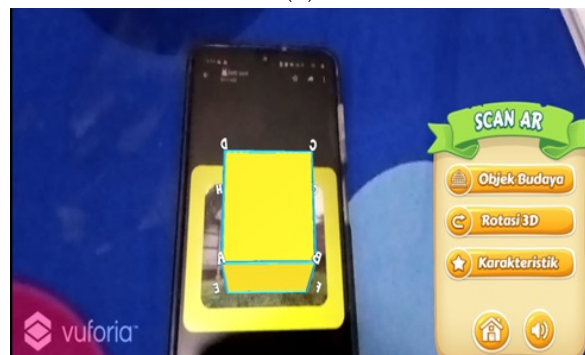
(C)



(D)



(E)



(F)



(G)

FIGURE 1. Types of student's solution in question 2. Figure (A) Opening Screen, (B) AR Home Menu Display, (C) Main Menu Display, (E) Display of material content, (F) Material Discussion Display, (G) AR Scan Display Figure, (H) Quiz Menu Display.

The effectiveness analysis, conducted using Cohen's *d* standard within the Hake framework for calculating effect size, revealed significant findings. Specifically, it was observed that the average score of the pretest was lower than that of the posttest. Similarly, the standard deviation of the

pretest scores was found to be less than that of the posttest scores. The calculated effect size (ES) yielded a value of 0.512, which falls into the medium category according to Cohen's *d* interpretation guidelines. This indicates that, on average, the students' learning outcomes after utilizing the

Augmented Reality (AR)-based learning media were higher compared to their learning outcomes before engaging with the AR learning media. This improvement suggests that the AR-based educational tool had a positive impact on enhancing the students' learning effectiveness, demonstrating its utility in facilitating a better understanding of the subject matter.

The comprehensive analysis of scholarly work underscores the pivotal role of Augmented Reality (AR) in reshaping educational paradigms, showcasing its substantial promise for enriching educational experiences (Akçayır & Akçayır, 2017; Wu et al., 2013). Employing the ADDIE model for crafting AR-driven educational tools mirrors the progressive trend of weaving cutting-edge technologies into the fabric of educational methodologies (Aydın et al., 2023; Saeidnia et al., 2022). Insights derived from the meticulous examination of mobile AR learning further affirm AR's aptness for educational endeavors (Hedberg et al., 2018), while in-depth investigations into AR's educational utilities shed light on its capacity to elevate learning dynamics (Hincapié et al., 2021).

The exploration into AR's applicability in mathematics instruction reveals its substantial potential as an instructive asset (Fernández-Enríquez & Martín, 2020). Research delving into AR's integration within elementary education reveals its critical role in enriching educational processes (Wang et al., 2021). Moreover, the innovative design of AR applications for children with dyslexia exemplifies AR's versatility in meeting varied educational needs, including those in special education (Lazo-Amado & Andrade-Arenas, 2023).

The initiative to develop AR-infused materials for imparting knowledge on geometry and spatial reasoning is in harmony with scholarly inquiries into AR's utility in mathematics and geometry education (Yuen et al., 2011). Additionally, the research evaluating AR's impact on educational improvement highlights the importance of employing AR as a tool for educational betterment. Comprehensive reviews on AR's educational potentials offer a broad perspective on its applicability across various learning environments (Yuen et al., 2011).

To summarize, the creation of AR-enhanced educational content, guided by the ADDIE framework for teaching geometry and spatial understanding, is well-aligned with the prevailing scholarly discourse, which delineates the numerous benefits and possibilities AR brings to the educational arena. The strategic fusion of AR into educational strategies is poised to revolutionize learning experiences, accommodating a wide array of learning preferences and requirements.

4. CONCLUSION

This research culminated in the creation of an educational application utilizing Augmented Reality (AR) technology, integrated with an ethnomathematical approach for teaching flat-sided solid figures to eighth-grade students at SMP/MTs. The development of this AR application followed the ADDIE model, which includes stages of Analysis, Design, Development, Implementation, and Evaluation. Validation surveys and student responses regarding the application's suitability and appeal indicate that the interactive multimedia product meets validity requirements and is considered highly engaging and ready for trial use.

The Effect Size (ES=0.512) derived from the study's findings suggests that the AR-based learning media developed is both appropriate and effective for instructional use, significantly aiding students in the learning process.

References

- Abdullah, A. A., Richardo, R., Rochmadi, T., Wijaya, A., & Nurkhamid, N. (2022). The Use of Ethnomathematics Learning Media Based on Augmented Reality for Madrasah Students. *AL-ISHLAH: Jurnal Pendidikan*, 14(1), 877–886. <https://doi.org/10.35445/alishlah.v14i1.1140>
- Afnan, A., Muhammad, K., Khan, N., Lee, M. Y., Imran, A. S., & Sajjad, M. (2021). School of the Future: A Comprehensive Study on the Effectiveness of Augmented Reality as a Tool for Primary School Children's Education. *Applied Sciences*, 11(11). <https://doi.org/10.3390/app1115277>
- Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 20, 1–11. <https://doi.org/10.1016/j.edurev.2016.11.002>
- Andriani, D., Widada, W., Herawaty, D., Ardy, H., Nugroho, K. U. Z., Ma'rifah, N., Anggreni, D., & Anggoro, A. (2020). Understanding the Number Concepts through Learning Connected Mathematics (CM): A Local Cultural Approach. *Universal Journal of Educational Research*, 8(3). <https://doi.org/10.13189/ujer.2020.080340>
- Aydın, A., Gürsoy, A., & Karal, H. (2023). Mobile care app development process: Using the ADDIE model to manage symptoms after breast cancer surgery (step 1). *Discover Oncology*, 14(1). <https://doi.org/10.1007/s12672-023-00676-5>
- Borba, M. de C., Aşkar, P., Engelbrecht, J., Gadanidis, G., Llinares, S., & Aguilar, M. S. (2016). Blended learning, e-learning and mobile learning in mathematics education. *ZDM*, 48(5). <https://doi.org/10.1007/s11858-016-0798-4>
- Çevikbaş, M., Greefrath, G., & Siller, H.-S. (2023). Advantages and challenges of using digital technologies in mathematical modelling education – a descriptive systematic literature review. *Frontiers in Education*, 8. <https://doi.org/10.3389/feduc.2023.1142556>
- Fernández-Enríquez, R., & Martín, L. D. (2020). Augmented Reality as a Didactic Resource for Teaching Mathematics. *Applied Sciences*, 10(7). <https://doi.org/10.3390/app10072560>
- Freitas, S. de, Rebolledo-Méndez, G., Liarokapis, F., Magoulas, G. D., & Poulouvassilis, A. (2009). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology*, 41(1). <https://doi.org/10.1111/j.1467-8535.2009.01024.x>
- Gay, G. (2002). Preparing for Culturally Responsive Teaching. *Journal of Teacher Education*, 53(2). <https://doi.org/10.1177/0022487102053002003>

- Gravemeijer, K., Stephan, M., Julie, C., Lin, F.-L., & Ohtani, M. (2017). What Mathematics Education May Prepare Students for the Society of the Future? *International Journal of Science and Mathematics Education*, 15, 105–123.
- Hedberg, H., Nouri, J., Hansen, P., & Rahmani, R. (2018). A Systematic Review of Learning Through Mobile Augmented Reality. *International Journal of Interactive Mobile Technologies (IJIM)*, 12(3). <https://doi.org/10.3991/ijim.v12i3.8404>
- Hincapié, M., Díaz, C., Valencia, A., Contero, M., & Güemes-Castorena, D. (2021). Educational applications of augmented reality: A bibliometric study. *Computers & Electrical Engineering*, 93. <https://doi.org/10.1016/j.compeleceng.2021.107289>
- Lazo-Amado, M., & Andrade-Arenas, L. (2023). Designing a Mobile Application for Children with Dyslexia in Primary Education Using Augmented Reality. *International Journal of Interactive Mobile Technologies (IJIM)*, 17(02). <https://doi.org/10.3991/ijim.v17i02.36869>
- Molina-Toro, J. F., Rendón-Mesa, P. A., & Villa-Ochoa, J. A. (2019). Research Trends in Digital Technologies and Modeling in Mathematics Education. *EURASIA Journal of Mathematics, Science and Technology Education*, 15(8). <https://doi.org/10.29333/ejmste/108438>
- Muwahiddah, U., Asikin, M., & Mariani, S. (2021). The Ability Solve Geometry Problems in Spatial Intelligence Through Project Based Learning-Ethnomathematics Assisted by Augmented Reality Apk. *Unnes Journal of Mathematics Education Research*, 10(A), 97–102.
- Poerwanti, J. I. S., Budiharto, T., & Mahfud, H. (2019). The Influence of Interactive Learning Media Based on Augmented Reality on the Achievement of Art Learning Result. *Proceedings of the Proceedings of the 1st Seminar and Workshop on Research Design, for Education, Social Science, Arts, and Hum.* <https://doi.org/10.4108/eai.27-4-2019.2286858>
- Richardo, R., Abdullah, A. A., Rochmadi, T., Wijaya, A., & Nurkhamid, N. (2023). Ethnomatematics learning media based on augmented reality for learning geometry: A needs analysis. *AIP Conference Proceedings*, 2540(1). <https://doi.org/10.1063/5.0105812>
- Rino, R., Ariyadi, W., Tri, R., Ahmad, A. A., Astri, W. A., & Khasanah, N. H. (2023). Ethnomathematics augmented reality: Android-based learning multimedia to improve creative thinking skills on geometry. *International Journal of Information and Education Technology*, 13(4), 731–737. <https://doi.org/10.18178/ijiet.2023.13.4.1860>
- Rochmadi, T., Richardo, R., Abdullah, A. A., Wijaya, A., & Nurkhamid, N. (2023). Design android-based learning media using augmented reality technology to support ethnomathematics materials at junior high school. *AIP Conference Proceedings*, 2540(1). <https://doi.org/10.1063/5.0105904>
- Rodríguez-Nieto, C. A., & Pastells, Á. A. i. (2022). Networking Between Ethnomathematics, STEAM Education, and the Globalized Approach to Analyze Mathematical Connections in Daily Practices. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(3). <https://doi.org/10.29333/ejmste/11710>
- Saeidnia, H. R., Kozak, M., Ausloos, M., Herteliu, C., Mohammadzadeh, Z., Ghorbi, A., Karajizadeh, M., & Hamsanzadeh, M. (2022). Development of a Mobile App for Self-Care Against COVID-19 Using the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) Model: Methodological Study. *JMIR Formative Research*, 6(9). <https://doi.org/10.2196/39718>
- Sudirman, S., Yaniawati, R. P., Melawaty, M., & Indrawan, R. (2020). Integrating ethnomathematics into augmented reality technology: Exploration, design, and implementation in geometry learning. *Journal of Physics: Conference Series*, 1521(3), 032006. <https://doi.org/10.1088/1742-6596/1521/3/032006>
- Sultan, M. F. (2023). The Development of Cultural-Based Mathematics Media Using Augmented Reality 3d With Ethnomathematics Concept to Support Independent Learning. *Proceedings of the International Conference on Future of Education*, 6(1), 41–52. <http://www.tiikmpublishing.com/proceedings/index.php/foe/article/view/1269>
- Wang, L., Sukmawarti, S., & Suwanto, S. (2021). The application of augmented reality in elementary school education. *Research, Society and Development*, 10(3). <https://doi.org/10.33448/rsd-v10i3.12823>
- 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 & Education*, 62. <https://doi.org/10.1016/j.compedu.2012.10.024>
- Yuen, S. C.-Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented Reality: An Overview and Five Directions for AR in Education. *Journal of Educational Technology Development and Exchange*, 4(1). <https://doi.org/10.18785/jetde.0401.10>