Integrating ethnomathematics into augmented reality technology: exploration, design, and implementation in geometry learning

S Sudirman1*, R P Yaniawati2, M Melawaty1 and R Indrawan2

1Program Studi Pendidikan Matematika, Universitas Wiralodra Indramayu, Jl. Ir. H. Juanda Km 3, Indramayu 45213, Indonesia
2Program Studi Pendidikan Matematika, Universitas Pasundan Bandung, Jl. Sumatera No 41, Bandung 40117, Indonesia

*Corresponding author: sudirman@unwir.ac.id

Abstract. This study aims to integrate ethnomathematics into augmented reality technology in learning geometry. The research method used was ADDIE (Analysis, Design, Development, Implementation, and Evaluation) approach. The stages used in this study consisted of (1) exploration; (2) design, (3) development; and (4) implementation. This study used two data analysis techniques: (1) qualitative was conducted for exploration studies, describing the design and development process; (2) quantitative was conducted to investigate the result of the use of integrated ethnomathematics AR technology implementation to 56 Mathematics pre-service teachers’ at Indramayu, Indonesia. The results showed that (1) ethnomathematics values in the form of uma lengge traditional house, ethnic karo houses, wa rebo traditional house, demak grand mosque, kaghati kolape kite can be used as marker objects on augmented reality technology and to explain geometry concept.; (2) The design stages consist of designing integration concepts, AR interfaces, and learning system development.; (3) the results of implementation analysis can (a) help to increase learning interaction activities (b) improve the understanding of concepts and geometry visualization, (c) provide information to Mathematics pre-service teachers’ related to ethnomathematics and local wisdom in Indonesia.

1. Introduction

During this decade, the augmented reality (AR) technology has developed rapidly [1]. The inclusion of AR technology in education, especially in learning, has given its own color to the interaction of teachers and students in the classroom [2, 3, 4, 5]. AR technology is able to bridge the interaction between abstract material concepts and the real world [6], [7], since its characteristics are capable of (1) combining virtual objects and real environments; (2) direct interact, (3) accurately identifying real objects [8]. Therefore, concluded that the use of AR technology can (1) grow kinesthetic abilities; (2) increase understanding of a learning material; (3) increase students' motivation and involvement in learning; (4) promote contextual linking[4].

In the context of mathematics learning, especially geometry material, the use of GeoGebra software assisted DDFC (Definition, Design, Formulation, and Communication) instructional model [9] and AR technology provides an alternative in representing geometric concepts in real terms. Related studies such as (1) performed an experiment on the use of augmented reality technology on teaching geometry and its impact on students' 3D thinking skills[10]; (2) studied the integration of AR technology into space
geometry teaching and learning activities in junior high school[11]; (3) applied a mobile Augmented Reality system (DiedricAR) in field geometry learning[12]; (4) studied the effect of Augmented Reality on space geometry material on student learning performance and attitudes[13]; (5) analyzed the use of augmented reality on visualization and spatial understanding in higher education[14].

Although the use of AR technology in teaching geometry has been widely used [11], [15], [16], there are no relevant studies that integrate ethnomathematics into AR technology. State that the mathematics learning process will be effective when there are social and cultural interactions through dialogue, language, and representation of symbolic meanings in mathematics[17]. Therefore, integrating ethnomathematics as cultural values is part of representing real environmental objects in mathematical concepts. AR technology can be integrated with contextual situations[18]. Contextual situations can be used as learning media to bridge real and virtual environments to encourage students to build knowledge in collaboration with other students [19]. In addition, AR technology can be integrated culture into introduce batik, a traditional Thai folk musical instrument on postcards, and traditional Sundanese food [17, 18, 19].

Based on the discussions above, this paper aims to integrate ethnomathematics in AR technology, with a focus on (1) ethnomathematics exploration which is integrated with AR technology; (2) producing the design development of integrated ethnomathematics geometry learning in AR technology; (3) implementation of integrated ethnomathematics geometry learning in AR technology;

2. Methods
The stages of this study refer to the ADDIE approach (Analysis, Design, Development, Implementation, Evaluation) by limiting it to (1) exploration analysis; (2) design; (3) development; and (4) implementation. The exploration analysis phase is performed by exploring the local wisdom literature in Indonesia from various reading sources. Furthermore, local wisdom in Indonesia is limited and analyzed based on the characteristics and linkages with ethnomathematic values. Based on this, local wisdom is obtained, such as (1) uma lengge traditional house; (2) ethnic karo houses; (3) mosque drum; (4) wa rebo traditional house; (5) kagahati kolape; (6) Demak grand mosque that has ethnomathematic values. The reason for the selection is based on the characteristics of local wisdom forms that represent geometry objects. Like uma lengge, the front roof resembles a triangle.

The second stage is AR designation which can be integrated with ethnomathematics. At this stage, the steps taken are modeling; texturing; 3D import; vuforia import; databaseupload and import. After the design, the third stage, development is performed by developing mobile learning that integrates ethnomathematics with AR. a number of pre-service mathematics teachers from a mathematics education study program at a university in a province located on the western island of Java, Indonesia, participated voluntarily in this research. The stages of implementation in Table 1.

| Table 1. Implementation Stages |
|--------------------------------|
| **Stages**               | **Activity**                                                                 |
| Selection of Geometry Topics. | 1. The user selects a topic to study. As geometry material builds a tube chamber.  |
|                          | 2. The user chooses markers that are relevant to the topic of the material.      |
| Study with AR            | 1. The user detects the selected marker.                                      |
|                          | 2. The user pays attention to the animation displayed in the AR menu.          |
|                          | 3. The user understands the concepts that are embedded in AR.                  |
|                          | 4. The user records the information displayed in AR.                           |
| Deepening of Material Concepts | 1. The users explore concepts through the "let's learn geometry" menu.        |
|                          | 2. The users understand the concepts that are embedded in AR.                  |
|                          | 3. The user records the information displayed in AR.                           |
| Assessment of material mastery | 1. The user selects the topic to be evaluated in the "evaluation" menu.        |
|                          | 2. The users work on the problems displayed in the menu.                       |
3. The user records answers.
4. Users can see the results of the workmanship.

The instruments used in this study were observation sheets, validation sheets, satisfaction questionnaires and geometry mastery tests. Data analysis techniques such as (1) qualitative are performed for exploration studies, describing the design and development process; (2) quantitative is performed to investigate the results of the use of integrated AR ethnomathematics technology implementation.

3. Result and Discussion
3.1 Exploration Analysis Phase

Indonesia is one of the countries that preserves a number of local wisdoms. Local wisdom exists in the form of traditions, languages, traditional houses, beliefs, traditional games, food, or other forms. Local wisdom, such as the Warebo traditional house in East Nusa Tenggara (NTT) has a characteristic in its shape that resembles a conical geometry. Therefore, mathematical values such as cones contained in local wisdom are called ethnomathematics.

The results of the exploratory analysis on the search of literature studies related to local wisdom in Indonesia that stores ethnomathematical values are presented in Table 2.

Table 2. Ethnomathematics Values on Indonesian Local Wisdom

| Names                  | Ethnomathematics Values                                                                 |
|------------------------|----------------------------------------------------------------------------------------|
| **Figure 1. Uma Lengge** Traditional house | Ethnomatematics value of Figure 1, including: (1) the square bottom terrace surrounds the four main pillars with an arrangement of areca midribs that forms the floor; (2) the roof of the house is shaped like a triangle. (3) The front and back of the roof are triangle shaped, with a triangular roof base. (4) The applied concept of triangle is a right-angled triangle. |
| **Figure 2. Karo Traditional house** | Ethnomatematics value of Figure 2, including: (1) the roof of the house is trapezoidal and triangular; (2) the exterior wall is divided into two parts, with the base formation of a square, rectangle, and trapezoid with an upper wall slope of 120°. |
| **Figure 3. Mosque Drum**     | Ethnomatematics value of Figure 3, including: (1) the shape of the drum resembles the concept of a tube in geometry; (2) the drum has two covers, one each on its end, made of cow leather or sheep skin; (3) the volume of the drum affects the produced sound; (4) the surface of the drum is made of wood or many are currently use a real wooden drum container. |
| **Figure 4. Wa Rebo Traditional house** | Ethnomatematics value of Figure 4, including: (1) Wa Rebo traditional house is cone-shaped; (2) first floor, this first floor is 11 meters in diameter; (3) the main mast stands on the first floor to support the main pillar, held by rattan ropes tied to three to four pegs; (4) the longest wall buffer is on the first floor, about 34.54 m (circumference of a circle = 2 phi r) and the higher the shorter the length of the circumference. |
Names | Ethnomathematics Values
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![Image](image1.png) | Kaghati Kolape Ethnomathematics value of Figure 5 is applied (1) form resembling the concept of a kite; (2) the kite’s frame is formed from two intersecting diagonal lines; (3) to create the kite’s frame, the community of Muna island use dried bamboo; (4) in addition, the coat of the kite is made from a square-shaped leaves.

![Image](image2.png) | Ethnomathematics value of Figur 6 including: (1) located in the width of the area and the shape of the mosque; (2) his mosque uses a three-tiered pyramid roof in the form of an isosceles triangle/a pyramid; (3) It turns out that this three-tiered pyramid roof model has a meaning, of which a believer needs to tread three important levels in their diversity: faith, islam, and ihsan.

### 3.2 Design Development Phase

In this stage, the integration of ethnomathematics, particularly in the concept of geometry into AR technology, AR design, and development of AR technology-based learning is performed. The phase of integrating ethnomathematics is by making a modeling of geometric concepts that exist in local wisdom.

![Image](image3.png) | The next step is performing (1) modeling; the process of developing the representation of geometric shapes of objects of local wisdom into 3D animation. (2) Texturing; the process of coloring 3D objects (3) import 3D; the process of inserting 3D objects into the Unity3D software. (4) vuforia import; the
process of detecting marker objects into the vuforia SDK (5) upload and import database software, the process of storing results (Figure 11).

Figure 11. Design development stages

Meanwhile, in the stages of developing AR technology-based learning, a local wisdom AR technology-based mobile learning or Etnicar-TG 4.0 is developed. Etnicar TG 4.0 is a mobile hearing that integrates ethnomathematics into AR on geometric material content. The Indonesian local wisdom Etnicar TG 4.0 menu consists of: (1) splashscreen and menu; (2) let’s study, displaying AR that explains geometric concepts; (3) let’s play, displaying geometric problem puzzles related to ethnomathematics; (4) evaluation (see Figures 12-14).

3.3 Implementation Phase
The implementation process is carried out on the topic of geometry material in the construction of curved side spaces, tubes. The implementation process begins with selecting a topic and selecting markers that are used in accordance with the topic of the tube, as shown in Figures 15-16.

Figure 12. Splashscreen and menu display
Figure 13. AR that explains geometric concepts display
Figure 14. Geometric problem puzzles related to ethnomathematics display
Figure 15. Tube Markers
Figure 16. Detection process
Next, the pre-service teacher of mathematics detects selected markers (Figure 17). After that, understand and record information related to the tube concept. Furthermore, the pre-service teacher of mathematics explores the concept of tubes through existing videos (Figure 18). After exploring the concept, then the pre-service teacher of mathematics works on the questions to see the extent of their understanding of the tube concept.

In addition, the results of the implementation of the use of geometry learning that integrates ethnomathematics into AR indicate that there is an increase in the learning interaction activities of pre-service teachers in the field of geometry and space. The activities of the mathematics teacher candidates observed in this study include: (1) activities using the AR application; (2) activities in solving ethnomathematics problem-solving puzzle; (3) activities in discussion; (4) activities in completing evaluation questions; (5) activities in asking technical questions. The results of the observation of the interaction of pre-service teacher activities at the first meeting obtained a percentage of 52.18% and classified as quite active. Meanwhile, in the fourth meeting, the percentage of classical learning activities was 69.40% and classified as active. The classical activities of pre-service mathematics teachers increased by 17.22%.

In addition, there was an evaluation on the understanding of the 56 pre-service mathematics teachers at Indramayu in completing 5 (five) geometry questions in the evaluation menu in the Etnicar TG 4.0 application. The evaluation results are expressed on a scale of 100, and the average value of conceptual understanding and geometry visualization of pre-service mathematics teachers before using the learning technique is 54. Meanwhile, the average score results of the evaluation at the end of the meeting are 66. This shows an increase in the understanding of concepts and geometry visualization before and after learning.

These results strengthen the previous studies which state that learning using AR can increase mathematical understanding, as [23] concluded that there were significant differences between using E-Learning and conventional such as (1) [13]who explained that the use of Augmented Reality can make students’ learning outcomes become better when compared to the use of conventional learning; (2) [12] who state that AR-based mobile learning is able to grow the potential of students’ spatial abilities, improve learning activities, and foster learning experiences for the users.

4. Conclusion
Based on the results of the study, the following conclusions are made (1) The results of the exploratory analysis on Indonesian local wisdom obtained ethnomathematics values in Lengge traditional house, Karo traditional house, mosque drum, Wa Rebo traditional house, and Great Mosque of Demak which can be used as geometric objects to be integrated into AR technology. (2) The AR design results are performed through 5 (five) stages, modeling, texturing, 3D import, vuforia import, database upload and import, and from the results of the design, ethnomathematics-based AR mobile learning were developed—called as Etnicar TG 4.0. (3) The results of the implementation analysis show an increase
in the interaction of learning activities, understanding of concepts, and also geometry visualization of the pre-service mathematics teachers.

5. References

[1] Bilyatdinova A, Karsakov A and Klimova A 2018 Existing Teaching Practices in Augmented Reality Existing Teaching in Augmented Reality Procedia Comput. Sci. 136 2018 5–15
[2] Bacc J Baldiris S Fabregat R Graf S and Kinshuk, 2014 Augmented Reality Trends in Education: A Systematic Review of Research and Applications Educ. Technol. Soc. 17, 4 p. 133–149.
[3] Bujak K R Radu I Catrambone R MacIntyre B Zheng R and Golubski G 2013 A psychological perspective on augmented reality in the mathematics classroom Comput. Educ. 68 536–544
[4] Cuendet S Bonnard Q Do-Lehn S and Dillenbourg P 2013 Computers & Education Designing augmented reality for the classroom Comput. Educ. 68 1–13
[5] Billinghamurst M and Duenser A, 2012 Augmented Reality in Classroom Computer Long. Beach. Calif 45 7 42–49
[6] Safar A H Al-Jafar A A and Al-Yousefi Z H 2017 The effectiveness of using augmented reality apps in teaching the english alphabet to kindergarten children: A case study in the state of Kuwait Eurasia J. Math. Sci. Technol. Educ. 13 2 417–440
[7] Gardón J and Acevedo J, 2019 Meta-analysis of the impact of Augmented Reality on students’ learning gains Educ. Res. Rev. 27 244–260
[8] Azuma R T 1997 A Survey of Augmented Reality Presence Teleoperators Virtual Environ. 6 4 355–385
[9] Kariadinata R and Yaniawati R P 2018 for improving students’ Van-Hiele geometry thinking skill The Implementation of GeoGebra Software-Assisted DDFC Instructional Model for Improving Students’ Van-Hiele Geometry Thinking Skill in International Conference on Education and Multimedia Technology 58–62
[10] Bili E Çat M Resnyansky D Şahin S and Billinghurst M 2019 An assessment of geometry teaching supported with augmented reality teaching materials to enhance students’ 3D geometry thinking skills Int. J. Math. Educ. Sci. Technol. 50 5 1464–5211
[11] Lin H K Chen M and Chang C 2015 Assessing the effectiveness of learning solid geometry by using an augmented reality-assisted learning system Interact. Learn. Environ. 23 6 799–810
[12] de Ravé E G Jiménez-Hornero F J Ariza-Villaverde A B and Taguas-Ruiz J 2016 DiedricAR: a mobile augmented reality system designed for the ubiquitous descriptive geometry learning Multimed. Tools Appl. 75 16 9641–9663
[13] Liu E Li Y Cai S and Li X 2019 The Effect of Augmented Reality in Solid Geometry Class on Students’ Learning Performance and Attitudes, in Lecture Notes in Networks and Systems 47 549–558
[14] González N A A 2018 Development of spatial skills with virtual reality and augmented reality Int. J. Interact. Des. Manuf. 12 1 133–144
[15] Liu E Li Y Cai S and Li X 2019 The Effect of Augmented Reality in Solid Geometry Class on Students’ Learning Performance and Attitudes in International Conference on Remote Engineering and Virtual Instrumentation 549–558
[16] Rohendi D Septian S and Sutarno H 2018 The Use of Geometry Learning Media Based on Augmented Reality for Junior High School Students IOP Conf. Ser. Mater. Sci. Eng. 306 012029
[17] Orey D and Rosa M 2008 Ethnomathematics and cultural representations: teaching in highly diverse contexts 27–46
[18] Johnson L Levine A Smith R and & Stone S, 2010, The Horizon Report, Austin, Texas.
[19] Karakus M Ersoulu A and Clark A 2019 Augmented Reality Research in Education: A Bibliometric Study Eurasia J. Math. Sci. Technol. Educ. 15 10
[20] Widiaty I Riza L S and Abdullah A G 2016 A Preliminary Study on Augmented Reality for Learning Local Wisdom of Indonesian Batik in Vocational Schools in International Conference
on Innovation in Engineering and Vocational Education 32–35

[21] Phunsa S 2015 Applying Augmented Reality Technology to Promote Traditional Thai Folk Instruments on Postcards in International Conference on Computer Graphics, Multimedia and Image Processing 64–68

[22] Yulia C Hasbullah H Nikmawati E E Mubaroq S R Abdullah C U and Widiaty I 2018 Augmented reality of traditional food for nutrition education MATEC Web Conf. 197 2–5

[23] Yaniawati R P 2013 E-Learning to Improve Higher Order Thinking Skills (HOTS) of Students J. Educ. Learn. 7 2 109–120

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