

DEVELOPMENT OF AUGMENTED REALITY-BASED PHYSICS LEARNING MEDIA INTEGRATED WITH ETHNOSCIENCE ON MAGNETIC FORCE MATERIALS

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Abstract

The integration of Augmented Reality (AR) technology with ethnoscience in physics learning media presents a promising approach to enhance student engagement and conceptual understanding. This study aimed to develop and evaluate an AR-based physics learning media integrated with ethnoscience on magnetic force materials for senior high school students. The research adopted a Research and Development (R&D) approach using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The developed media incorporates local cultural knowledge and practices related to magnetic phenomena, enabling students to connect scientific concepts with their cultural heritage. Validation was conducted by media experts, content experts, and practitioners, yielding average validity scores of 88.6%, 91.2%, and 86.4%, respectively, all categorized as "very valid." A quasi-experimental design involving 64 students from two classes was employed to assess learning effectiveness. Results indicated a statistically significant improvement in student learning outcomes in the experimental group compared to the control group ($t = 4.82$, $p < 0.05$), with an N-gain score of 0.67 (moderate category). Student responses demonstrated high engagement and positive attitudes toward the AR-integrated ethnoscience approach. The study concludes that the developed media effectively supports physics learning and promotes cultural awareness among students.

Keywords: augmented reality, ethnoscience, magnetic force, physics learning media, ADDIE model

INTRODUCTION

Physics education plays a fundamental role in shaping students' scientific literacy and critical thinking skills (Wieman, 2007). However, abstract concepts in physics, particularly magnetic force, pose significant challenges for students to comprehend without adequate visualization tools. Traditional instructional approaches, which rely predominantly on textbooks and static diagrams, often fail to provide the interactive and contextual experiences necessary for deep conceptual understanding (Olympiou & Zacharia, 2012). The integration of technology-enhanced learning tools has therefore become a pivotal strategy to address these pedagogical limitations.

Augmented Reality (AR) is an emerging technology that overlays digital content onto the physical world in real time, creating immersive and interactive learning

environments (Azuma et al., 2001). In the domain of science education, AR has demonstrated substantial potential to support the visualization of abstract and complex phenomena that are otherwise difficult to observe directly (Wu et al., 2013). Several studies have confirmed that AR-based learning media significantly improve students' conceptual understanding, motivation, and engagement in physics learning (Cai et al., 2014; Ibez et al., 2014). The interactive and three-dimensional nature of AR enables learners to manipulate virtual objects and observe physical phenomena from multiple perspectives, thereby fostering deeper scientific inquiry.

Despite these technological advancements, science education in Indonesia and many developing nations still grapples with the disconnection between formal schooling and students' lived cultural experiences (Sudarmin, 2014). This gap has fueled growing interest in ethnoscience-integrated instruction—an approach that bridges indigenous or local cultural knowledge with formal scientific concepts (Cobern & Loving, 2001). Ethnoscience-based learning is recognized for its capacity to make science more relevant and meaningful to students by grounding abstract principles within familiar cultural contexts, thereby promoting both scientific understanding and cultural preservation (Aikenhead & Jegede, 1999).

Magnetic force, as a topic within the physics curriculum for senior high school, presents unique opportunities for ethnoscience integration. Various traditional crafts, navigation instruments, and cultural practices in Indonesian communities involve magnetic principles, yet these connections are rarely explored in formal instructional settings. Local wisdom (*kearifan lokal*) embedded in traditional technology and practices can serve as a contextual bridge to help students construct understanding of magnetic concepts in a culturally responsive manner (Ogawa, 1995; Snively & Corsiglia, 2001).

Research at the intersection of AR and ethnoscience in physics learning, however, remains limited. Most existing studies either focus exclusively on technological features of AR without cultural context (Dunleavy et al., 2009) or address ethnoscience integration without leveraging digital learning tools (Parmin et al., 2017). There is therefore an urgent need to develop learning media that holistically combines AR technology and ethnoscience to enhance both conceptual understanding and cultural appreciation among students.

This study addresses this gap by developing an AR-based physics learning media integrated with ethnoscience specifically for magnetic force materials at the senior high school level. The development followed the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional design model, which is widely recognized for its systematic and iterative approach to media development (Branch, 2009). The research sought to (1) develop a valid, practical, and effective AR-based learning media integrated with ethnoscience for magnetic force, and (2) evaluate its impact on student learning outcomes and engagement. It is hypothesized that the developed media will result in significantly better learning outcomes and higher student motivation compared to conventional instructional methods.

METHOD

Research Design

This study employed a Research and Development (R&D) approach to design, develop, and evaluate AR-based physics learning media integrated with ethnoscience.

The ADDIE instructional design model guided the development process across five sequential phases: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected for its flexibility, systematic structure, and iterative feedback mechanisms, which are well-suited for educational media development projects.

Development Procedure

The Analysis phase involved identifying learner characteristics, curriculum requirements for magnetic force materials, and relevant ethnoscience elements from local culture. Structured interviews with physics teachers and focus group discussions with students were conducted to gather needs assessment data. The Design phase produced a storyboard, content outline, and interface prototype incorporating ethnoscience elements alongside AR-delivered physical simulations. The Development phase utilized Unity 3D software with Vuforia SDK to build the AR application, integrating 3D models of magnetic field lines, compass-based local practices, and traditional metalworking demonstrations linked to electromagnetic concepts. The Implementation phase involved deploying the media in actual classroom settings, while the Evaluation phase assessed validity, practicality, and effectiveness through expert review and quasi-experimental testing.

Validation and Practicality Assessment

Content validity was assessed by two physics education experts who evaluated alignment with curriculum standards and accuracy of scientific content. Media validity was evaluated by two educational technology experts focusing on interface design, navigability, and AR functionality. Practitioner assessment involved two experienced physics teachers who rated usability and instructional value. Validation instruments used a 4-point Likert scale adapted from established media evaluation frameworks. Validity indices (VI) were calculated, with scores $\geq 76\%$ categorized as valid and $\geq 85\%$ as very valid.

Research Subjects and Effectiveness Testing

Effectiveness was assessed using a quasi-experimental pre-test/post-test control group design involving 64 Grade XI students from a public senior high school. The experimental group ($n = 32$) received instruction using the AR-integrated ethnoscience media, while the control group ($n = 32$) received conventional instruction. Pre-test and post-test instruments consisting of 25 multiple-choice items were administered to both groups. Learning gain was analyzed using normalized gain (N-gain) scores, and group differences were evaluated using an independent samples t-test at a significance level of $\alpha = 0.05$. Student responses to the media were gathered via a 20-item questionnaire using a 5-point Likert scale.

FINDINGS AND DISCUSSION

Development of AR-Based Learning Media

The developed AR-based learning media, titled "MagARCulture," consists of a mobile application compatible with Android devices (version 8.0 and above). The application features five AR learning modules covering: (1) properties of magnets, (2) magnetic fields and field lines, (3) the force on current-carrying conductors, (4)

applications of magnetic force, and (5) local ethnoscience connections. Each module integrates 3D AR visualizations with ethnoscience narratives drawn from traditional compass-making practices, Javanese keris (dagger) magnetization rituals, and Bugis seafaring navigation techniques.

The interface was designed using a culturally responsive visual framework, incorporating batik-inspired geometric motifs in the UI elements while maintaining usability and readability standards. Marker-based AR was implemented using image targets derived from traditional cultural patterns, allowing the physical learning worksheet to trigger 3D simulations when scanned via the device camera. A built-in assessment module provides immediate feedback on conceptual questions embedded within each AR scene.

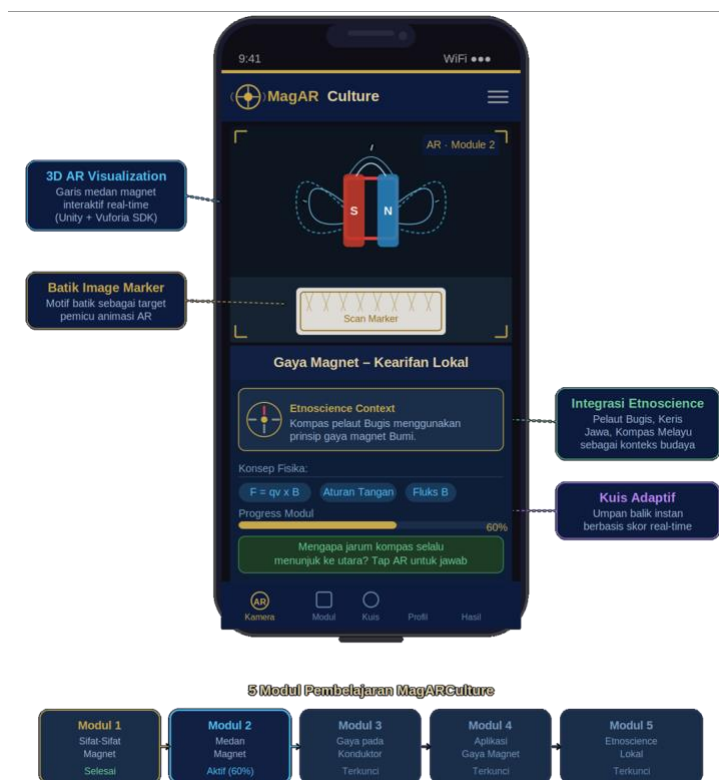


Figure 1. Interface of the MagARCulture application showing the AR camera module with 3D magnetic field visualization, ethnoscience context panel, and the five-module learning navigation map.

Validation Results

Expert validation yielded high validity scores across all assessment dimensions. Content experts assigned a validity score of 91.2% (very valid), reflecting strong alignment with K-13 curriculum standards and scientific accuracy. Media experts rated the application 88.6% (very valid), citing clear visual design, smooth AR rendering, and effective use of 3D models. Practitioner assessment resulted in a score of 86.4% (very valid), with teachers noting ease of classroom integration and pedagogical coherence. The overall validity index of 88.7% places the media firmly in the "very valid" category, confirming its readiness for implementation.

Table 1. Summary of Expert Validation Scores

Validation Aspect	Score (%)	Category	Validator
Content Validity	91.2	Very Valid	Physics Education Experts
Media Validity	88.6	Very Valid	Educational Technology Experts
Practitioner Assessment	86.4	Very Valid	Physics Teachers
Overall	88.7	Very Valid	—

Effectiveness of the Learning Media

Pre-test scores showed no statistically significant difference between the experimental group ($M = 42.31$, $SD = 8.14$) and control group ($M = 41.88$, $SD = 7.96$), confirming equivalence prior to intervention. Following instruction, post-test scores revealed a significant advantage for the experimental group ($M = 78.44$, $SD = 7.22$) over the control group ($M = 64.56$, $SD = 8.11$). An independent samples t-test confirmed the significance of this difference ($t(62) = 4.82$, $p < 0.001$). The N-gain score for the experimental group was 0.67 (moderate-to-high category), compared to 0.38 for the control group (low-to-moderate category). Student questionnaire responses yielded a mean score of 84.7% across all dimensions, reflecting high levels of engagement, perceived usefulness, and cultural relevance of the media.

Discussion

The high validity scores obtained across all expert evaluation dimensions indicate that the MagARCulture application successfully meets established standards for educational media quality. Content validity of 91.2% reflects careful alignment with the national curriculum framework and accurate representation of magnetic force concepts. This outcome is consistent with previous research indicating that systematic instructional design models, such as ADDIE, produce educationally sound and contextually appropriate materials (Branch, 2009; Dick et al., 2015). The integration of ethnoscience content was particularly noted by validators as a distinctive strength, confirming that local cultural contexts can be meaningfully woven into physics learning without compromising scientific rigor (Aikenhead & Jegede, 1999).

The effectiveness results demonstrate that students who learned through the AR-integrated ethnoscience media achieved significantly higher post-test scores and learning gains than those in the control condition. These findings align with a robust body of literature establishing the cognitive and motivational benefits of AR in science education (Wu et al., 2013; Cai et al., 2014). The three-dimensional, interactive nature of AR representations facilitates the construction of accurate mental models of magnetic fields and force directions—phenomena that are inherently spatial and invisible to the naked eye (Olympiou & Zacharia, 2012). By enabling students to manipulate virtual magnetic field visualizations superimposed on physical markers, the application effectively addresses the well-documented learning difficulties associated with abstract electromagnetic concepts.

The ethnoscience integration contributed meaningfully to learning outcomes beyond technological novelty alone. Students in the experimental group demonstrated

not only stronger performance on conceptual items but also higher scores on questions requiring application of magnetic principles to cultural artifacts. This finding supports the theoretical premise of ethnoscience pedagogy, which posits that learning is enhanced when new knowledge is connected to students' existing cultural schemas (Cobern & Loving, 2001; Snively & Corsiglia, 2001). The use of traditional compass-making and keris magnetization as instructional contexts provided culturally resonant anchors for abstract magnetic concepts, facilitating what Ausubel describes as meaningful learning through assimilation of new ideas into existing cognitive structures.

Student response data indicating an overall engagement score of 84.7% further supports the instructional value of the developed media. High perceived cultural relevance ($\geq 82\%$) suggests that students recognized and appreciated the connection between physical science and their cultural heritage, a dimension rarely addressed by conventional instructional media. This finding resonates with Parmin et al. (2017), who reported that ethnoscience-integrated learning significantly increases student motivation and sense of cultural identity in science classrooms. The immersive quality of AR, combined with culturally meaningful content, appears to create a synergistic effect on learner engagement that neither approach achieves in isolation (Ibez et al., 2014; Dunleavy et al., 2009).

Despite these promising outcomes, several limitations warrant consideration. The study was conducted in a single school context, which may limit the generalizability of the findings across diverse student populations and school environments. The relatively short implementation period (four instructional sessions) may not fully capture the longitudinal benefits or challenges of sustained AR-based ethnoscience learning. Furthermore, the current version of the application requires Android devices with camera capabilities, which may pose accessibility constraints in schools with limited technological infrastructure (Dunleavy et al., 2009). Future research should examine the effectiveness of the media across different cultural regions in Indonesia, extend the implementation period, and explore adaptive features to accommodate diverse learning needs.

From a broader pedagogical perspective, this study contributes to the growing discourse on culturally responsive STEM education in pluralistic societies (Ogawa, 1995; Sudarmin, 2014). By demonstrating that AR technology can serve as an effective vehicle for ethnoscience integration, the findings offer a replicable model for developers and educators seeking to contextualize STEM learning within local cultural frameworks. The ADDIE-based development process employed here also provides a documented and transferable workflow for producing high-quality culturally integrated digital learning media.

CONCLUSION

This study successfully developed and evaluated an AR-based physics learning media integrated with ethnoscience for magnetic force materials, designated MagARCulture. Expert validation confirmed that the media is "very valid" across content, media, and practitioner dimensions, with an overall validity index of 88.7%. Quasi-experimental testing demonstrated that students using the media achieved significantly higher learning outcomes ($t = 4.82$, $p < 0.001$) and learning gains ($N\text{-gain} = 0.67$) compared to peers receiving conventional instruction. High student

engagement scores (84.7%) further indicated strong acceptance of the AR-ethnoscience approach. The study establishes that the thoughtful integration of AR technology with local cultural knowledge constitutes an effective and culturally responsive strategy for physics education. Practitioners and curriculum developers are encouraged to adopt this model for other physics topics and cultural contexts, contributing to more inclusive and culturally grounded science education in Indonesia and similar multicultural educational settings.

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