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THE EFFICACY OF AUGMENTED REALITY MAGIC CARDS IN ENHANCING ANTI-SMOKING AWARENESS AMONG ELEMENTARY STUDENTS

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Abstract— *Child smoking in Indonesia remains a critical public health challenge, with national surveys indicating high prevalence among school-aged children due to ineffective traditional media. Previous research on Augmented Reality (AR) in education has largely focused on science and literacy, and while AR has been explored for smoking prevention in general contexts, empirical studies integrating structured instructional design models within rural primary schools remain underrepresented. This study developed Magic Card, a marker-based AR application to improve students' understanding of the impact of smoking on the body's organs. The Alessi & Trollip instructional design model was adopted for its systematic approach to integrating pedagogical requirements with technical software development constraints. Development proceeded through planning, design, and implementation stages, integrating 3D anatomy models, interactive animations, and gamified quizzes. Black-box testing showed a 93.6% success rate, while Level of Detail (LOD) optimisation reduced rendering latency by up to 70%. Learning effectiveness was assessed with students at SD Inpres Abeale 1 Sentani using N-Gain analysis, yielding a score of 0.71 (high effectiveness). Preliminary results from this small-scale pilot suggest that Magic Card has strong potential to enhance students' health literacy and risk perception. These findings indicate the potential of AR as an immersive and relevant health education medium for preventing early smoking behaviour, especially in areas with limited educational resources.*

Keywords: *Augmented reality, children's health education, gamification, magic card, smoking prevention.*

INTRODUCTION

Smoking has become a global health crisis among children [1], [2]. Indonesia is facing a very worrying situation. National data has shown a worrying trend [3]. The 2023 Indonesian Health Survey (SKI) shows that the number of active smokers has reached 70 million people, with 7.4% of them coming from the vulnerable age group aged 10-18 years. [4]. The World Health Organisation (2023) reports that 23.4% of students in Indonesia have had experience trying smoking, indicating widespread exposure to tobacco products among adolescents. This issue is further compounded by interrelated social factors. Moreover, while many Indonesian teenagers possess a general awareness of smoking hazards, their comprehensive understanding remains limited. [5].

Boys are under social pressure to show their masculinity and maturity by smoking, and 21 per cent of them die prematurely from tobacco-related diseases[6]. The risk also extends to non-smoking family members. Exposure to secondhand smoke in non-smoking women is high due to proximity to male smokers at home; about 52.7% of women are exposed, and this exposure is recognised to harm women and children [7], [8]. Smoking households, on average, allocate the majority (10.7%) of their monthly budget to tobacco products; this figure is higher compared to spending on staples, meat, or vegetables [9].

A study in Papua found that 13.2% of primary school children had smoked, and most of them (61.4%) had a low level of knowledge about the dangers. [10]. Exposure to substances at a young age interferes with ongoing neurodevelopment, creating long-term susceptibility to addiction [11]. Some interventions carried out in the school environment are web-based (such as video games, m-health games, or e-learning) that aim to prevent addictive behaviour and develop social skills, especially the ability to resist peer pressure to smoke [12]. Previous studies have demonstrated that digital game programs can increase students' knowledge about the risks and consequences of smoking [13]. Improving students' knowledge in rural areas with limited resources requires a tailored approach due to diverse social norms and unique challenges [14], [15], [16]. Conventional methods, such as lectures and textbooks, are considered less effective at fostering deep engagement and simulating the real pressures children face [17]. These limitations leave a gap for an intervention that is not only informative but also immersive and capable of shaping conceptual understanding through hands-on experience.

Augmented Reality (AR) is a technology that superimposes virtual objects onto real environments in real time, creating an interactive and immersive learning experience via smartphones or tablets. [18]. In contrast to conventional media, AR can transform abstract health concepts into 3D visualisations that can be explored from multiple angles [19]. The effectiveness of the AR approach is consistent with Embodied Cognition Theory, which holds that cognitive understanding is shaped by physical experience and sensory perception [19], [20]. In the context of smoking prevention, this theory explains that kinesthetic interactions, such as twisting, enlarging, and dissecting 3D models of the heart or lungs damaged by cigarettes through gadgets, can create a more intuitive and memorable understanding than simply reading textual descriptions. AR allows children not only to know, but also to see and feel the consequences of smoking more, which can change their perception of risk more effectively. This ability is used in the Magic Card application developed in this study. Physical cards with markers will create visual simulations of the affected organs, enabling students to actively engage in learning and investigate the dangers of smoking in greater depth [21].

Thus, AR is not merely an entertainment tool but a cognitive medium that can enhance conceptual understanding [22]. Research on the use of AR as an educational medium has demonstrated its potential to improve students' Literacy skills. [23]. Although various studies have shown that Augmented Reality (AR) is efficacious in improving students' understanding of abstract concepts and learning motivation, most prior studies have focused on science, literacy, or general 3D object recognition [24]. Prior studies on the use of AR specifically for education on the dangers of smoking in elementary school-age children remain underrepresented, especially in the context of rural areas such as Papua, which have social, cultural, and educational infrastructure challenges that are different from those in urban areas.

To clarify how the AR Magic Cards systematically influence and enhance anti-smoking awareness among young learners, a dedicated theoretical framework is developed by integrating Embodied Cognition Theory and Gamification Theory (as illustrated in Figure 1). The cognitive mechanism operates through a three-tiered progression: Input, Cognitive Processing, and Behavioral/Awareness Outcome. At the Input stage, the intervention departs from passive traditional media by introducing physical manipulation (twisting, aligning, and scanning the Magic Cards) coupled with high-fidelity 3D structural renderings of internal organs. According to Embodied Cognition Theory, human cognitive structures are deeply rooted in bodily experiences and sensorimotor interactions. When a student physically interacts with the digital artefact to view a stark, three-dimensional contrast between a healthy organ and a smoke-damaged lung, the brain processes this concrete spatial feedback much faster than abstract textual instruction.

This active engagement leads to the Cognitive Processing stage, where the realistic visual stimulus triggers an internal threat appraisal. The interactive visualization serves as an immersive "fear appeal" that makes the internal, invisible dangers of smoking personally relevant and emotionally resonant to the child. Simultaneously, the system leverages Gamification Theory through its 20-item randomized quiz module. Instead of rote memorization, students undergo active recall reinforced by immediate visual pop-ups and audio feedback for correct answers. This dual-coding mechanism (spatial AR visuals combined with game-based reinforcement loops) reduces cognitive load while maximizing information retention.

Ultimately, at the Outcome stage, this combined pedagogical flow bridges the gap between knowledge and attitude. The multisensory experience permanently alters the student's risk perception, transforming basic factual memorization into a deeply embedded anti-smoking awareness and an increased psychological resistance toward future peer smoking pressures.

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Previous research on AR media for health education has generally not integrated systematic instructional design models, such as those by Alessi & Trollip, resulting in an incomplete structuring of the pedagogical and technical aspects. Although recent studies have begun to use N-Gain to measure learning gains from AR media in elementary classrooms, such evaluations have rarely addressed health education topics, leaving improvements in students' health literacy largely unmeasured [22], [25]. For example, AR combined with problem-based learning produced a high N-Gain (0.78) compared with two-dimensional media (0.43) among elementary students in Ternate, eastern Indonesia [25]; however, such standardised quantitative evaluations remain limited in health education for early-grade learners.

To address this gap, this study has combined marker-based AR, 3D anatomical visualisation, and gamification (interactive quizzes) to increase anti-smoking awareness among elementary school students. In fact, a multisensory approach like this has the potential to provide a more immersive learning experience and have an impact on children's risk perception of the dangers of smoking. This study aims to assess the effectiveness of Augmented Reality (AR) Magic Cards in increasing anti-smoking awareness among elementary school students. This study evaluates the increase in students' knowledge of the dangers of smoking following the use of AR Magic Cards. It analyses the level of student involvement and learning motivation when using AR media compared with conventional media.

MATERIALS AND METHODS

This study employs a Research and Development (R&D) approach, adopting the Alessi & Trollip instructional design model, which is widely recognised for its comprehensiveness in the development of interactive multimedia. [26] This model was chosen because it can systematically integrate pedagogical, technical, and evaluative aspects, making it suitable for producing Augmented Reality (AR)-based educational media for elementary school students. After the media is produced, its effectiveness is measured using N-Gain to quantify the increase in students' anti-smoking awareness before and after its use.

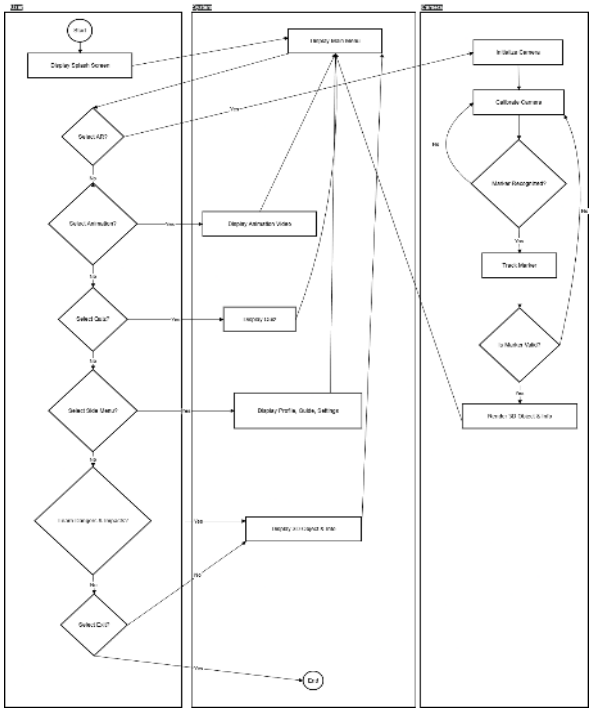
The research focuses on developing the Magic Card AR application as a learning medium to enhance students' understanding of the dangers of smoking, with a case study at SD Inpres Abeale 1, Sentani, Papua. The first phase in this model is Planning, which includes analysing needs, identifying user characteristics, and formulating learning objectives.



Source: (Research Results, 2025)

Figure 1. Theoretical Framework of AR Magic Cards Toward Anti-Smoking Awareness

At this stage, the researcher conducts initial observations and discussions with teachers to assess students' knowledge of the dangers of smoking and to determine relevant educational content. In addition, the researchers established the application's technical specifications, including the selection of the AR platform, the type of marker used, and the compatible devices. This planning stage ensures that media development is grounded in real needs in the field and aligned with the learning context in elementary schools.



Source: (Research Results, 2025)

Figure 2 Application Architecture and System Interaction Flowchart

The initial stage began with a field study at SD Abeale 1 Sentani, where interviews with teachers and students revealed the need for more engaging visual learning media than conventional textbooks

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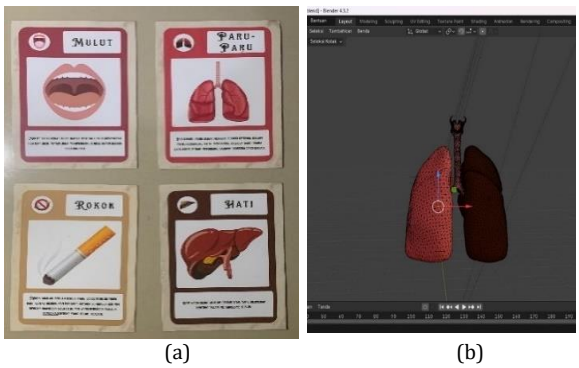
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(as shown in Figure 3). As a result, 80% of students expressed a preference for interactive content, while teachers admitted difficulty explaining abstract concepts such as organ damage caused by smoking. Based on these findings, our researchers designed the application's technical specifications, utilising Unity 3D as the core platform. The Vuforia SDK for marker tracking, recognised for its robust marker-based tracking capabilities and seamless integration with Unity, has become a near-standard tool for AR development [24]. We also work with Blender 4.2.0 for 3D object modelling.



Source: (Research Results, 2025)
Figure 3 Interview with The Teacher

The next stage is Design, which focuses on designing the application structure, interaction flow, and visual elements. In this phase, researchers compile a storyboard, create a child-friendly user interface, and determine the interaction model between physical cards (Magic Cards) and 3D objects rendered via AR technology (Figure 4). Content design includes developing educational narratives, animating body organs affected by smoking, and preparing interactive quizzes as evaluation instruments. The design principles emphasise simplicity, readability, and visual appeal to align with the cognitive characteristics of elementary school students.



(a) (b)
Source: (Research Results, 2025)
Figure 4. Marker (a) and 3D Model (b)

The third phase is Development, which involves implementing the design to produce a usable product. At this stage, the researcher develops applications using AR development software, creates 3D models, integrates animations, and links physical markers to digital content. Once the initial prototype is complete, a series of internal tests is conducted to ensure system stability, marker tracking accuracy, and smooth interaction. Revisions are carried out iteratively based on trial findings, ensuring that the resulting applications meet the established technical and pedagogical standards.

During these three phases, the study applied three parallel attributes from the Alessi & Trollip model: Standards, Continuous Evaluation, and Project Management. Standard attributes ensure that every component of the application meets the quality criteria in both educational content and technical aspects. Continuous evaluation is conducted through phased trials, including pre-tests to assess media effectiveness using N-Gain analysis. Meanwhile, project management ensures that the entire development process proceeds on schedule, is well coordinated, and is systematically documented.

RESULTS AND DISCUSSION

Development Outcomes

The user interface incorporates visual elements created with Canva to ensure intuitive navigation, while an introductory video produced using Filmora and Canva provides background information on the dangers of smoking. The image tracker is designed as a book, with a magic card that serves as a companion to deepen students' understanding of the dangers of smoking.

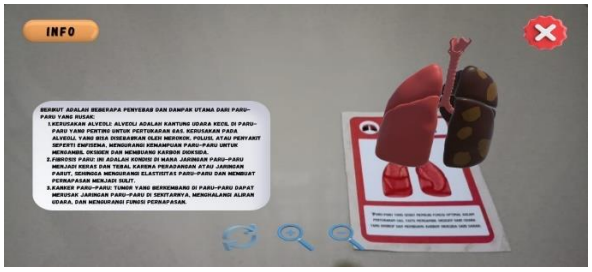


Source: (Research Results, 2025)
Figure 5. Main Menu

System integration is carried out in Unity, utilising Vuforia's AR Camera and Image Target features. Interactivity is implemented using C# scripts that trigger audio when a marker is detected.

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Source: (Research Results, 2025)
Figure 6. Magic Card as Marker and The Object.

The Magic Card Augmented Reality (AR) app exhibited performance issues during initial functional testing, characterised by latency in rendering 3D models. This technical obstacle manifests as a 1-2 second delay during model loading. To overcome this barrier, the development team implemented the Level of Detail (LOD) framework in Unity. This technique dynamically reduces the geometric complexity of 3D objects as they move farther from the user's camera, thereby reducing the computational burden on the rendering pipeline.

LoD begins with identifying the problem through black-box testing, which confirms that rendering latency is the core issue. Furthermore, the solution implemented not only integrated the LOD system but also optimised the 3D asset, reducing its polygon count from 10,000 to 4,000 vertices to improve performance on mobile devices. This optimisation ensures that applications can still run smoothly on cellphones with standard or older model specifications, which were crucial steps to ensure accessibility in a rural educational context

Functional testing demonstrated a 93% success rate in marker detection, although constraints such as 3D object rendering latency (1.8 seconds) were mitigated through Level of Detail (LOD) optimisation.

Functional Testing

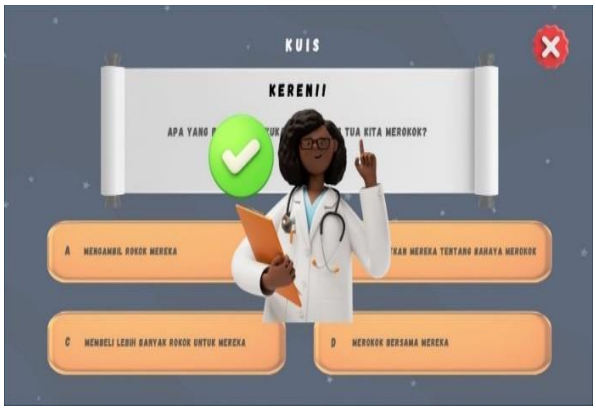
Functional testing of the Magic Card application employs black-box testing to verify that each feature conforms to the design specifications. Black-box testing for this application focuses on the application's external behaviour without examining its internal code. The tester examines only the generated Inputs, Applications, and Outputs. The tester acts as an end user (a teacher and a student) who interacts only with the application interface. This test comprises 47 scenarios to verify that the output meets the desired specifications. Some scenarios, such as button functions, Augmented, and qui, are included in this section—Blackbox testing Success Rate: 93.6% (44/47 successful test cases). Markers were not detected in low-light conditions (in 2 cases) as often. Crashes when switching between menus on Android version <10 (1 case). The following is a summary of the Black Box Testing results in Table 1.

Table 1. Blackbox Testing Result

Module	Success Rate	Bug Major
Menu AR	95%	Latency model 3D
Quiz	89%	Delayed audio feedback
Navigation	100%	Rotation button

Source: (Research Results, 2025)

This educational quiz was developed using a C# scoring system and comprises 20 randomly selected questions on the effects of smoking. Each correct/incorrect answer triggers visual feedback (a pop-up icon) as shown in Figure 7.



Source: (Research Results, 2025)
Figure 7.Quizzes and Pop-Up Display for True Answers

The user trial involved nine students and one teacher. As a result, the interface was rated as intuitive (score 4.2/5 in the survey). However, 25% of students initially had trouble finding the object rotation buttons, so an animation tooltip was added to assist them. From a technical perspective, the application's size (148 MB) poses a challenge due to the inclusion of 3D assets and video, which is mitigated by using ASTC 6x6 textures for compression. Key learning points include the importance of asymmetric marker patterns (which are 20% more accurate than symmetric patterns) and the avoidance of competitive features, such as leaderboards, to maintain an educational focus.

User Trial Findings

The implementation of the activity begins with an introduction to the tools, an explanation of their use and benefits, and an adaptation to the school-provided learning materials. In the implementation phase, 86% of students reported that the interface was "easy to understand," and teachers rated the content as having a positive

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educational impact on students. Some obstacles faced include 20% of students having difficulty scanning markers without initial guidance. The teacher provides additional audio narration for students with low reading ability. These findings align with gamification theory, which states that interactive elements (AR + quizzes) increase engagement. However, there is a need to improve usability for children in class 5, for example, by using video-based tutorials.



Source: (Research Results, 2025)
Figure 8. Explanation Process for Students Source

Learning Effectiveness

To evaluate the initial usability, user engagement, and immediate short-term knowledge retention of the prototype, a single-group pre-test/post-test pilot evaluation was conducted with a cohort of 9 fifth-grade students and 1 teacher at SD Inpres Abeale 1 Sentani. The intervention took place in a classroom setting during a 45-minute session. A 10-minute pre-test was administered immediately prior to the AR interaction, followed by a 25-minute learning session using the Magic Cards, and concluded with a 10-minute post-test. The results of the Normalised Gain (N-Gain) calculation are summarised in the following table:

Table 2 N Gain Score

Parameter	Average Score
Skor Pre-test	57.33
Skor Post-test	87.33
Average Score N-Gain	0.71
Average Score N-Gain (%)	71.33%
N-Gain Categories	High
Interpretation of Effectiveness	Quite Effective

Source: (Research Results, 2025)

The data in Table 2 showed a significant improvement in student comprehension, with the average score rising from 57.33 to 87.33. An N-Gain score of 0.71 placed this intervention in the High Category. In percentage terms, a score of 71.33% indicates that the AR Magic Card learning media is "Quite Effective" in delivering educational materials on the dangers of smoking in the elementary school environment.

The findings demonstrate that AR-based Magic Cards effectively enhance students' understanding of the hazards of smoking. The high N-Gain score aligns with previous studies showing that AR improves conceptual learning by enabling multisensory engagement and interactive exploration. The ability to visualise organ damage in 3D appears to strengthen risk perception, supporting Embodied Cognition Theory, which posits that learning is reinforced through physical interaction with digital objects. Crogman [27] affirms that AR and MR significantly enhance experiential learning because they allow students to "experience" concepts through multisensory interaction. Positive usability feedback suggests that AR is well-suited for young learners, particularly in rural contexts where access to advanced educational tools is limited. Studies conducted by Sathyapriya [28] shows that AR increases children's engagement and motivation.

The integration of gamification elements, such as quizzes and visual feedback, further increased student motivation, consistent with Gamification Theory. Lorena [29] states that gamification significantly increases student motivation and engagement. In addition, it improves knowledge retention and develops key skills, including problem-solving and decision-making. This makes learning more engaging and participatory by leveraging human motivation to pursue achievement and overcome challenges. The use of quizzes can also deepen students' engagement with learning materials and provide intrinsic motivation, thereby fostering student independence [30].

However, challenges such as marker dependency and application size highlight the need for further optimisation to improve accessibility and scalability [28], [31]. The technical optimisation of the AR Magic Card, in particular the implementation of a Level of Detail (LOD) framework and the reduction of 3D asset polygons from 10,000 to 4,000 vertices, is critical to ensuring the application's stability on mobile devices. This decision was driven by the need for 'scalable' and 'inclusive' educational tools that could work effectively on low-end smartphones, which are commonly used by students in rural areas. In rural Papua, limited hardware and ICT infrastructure often hinder the adoption of advanced learning media. By reducing rendering latency through vertex reduction, the app achieves high success rates in functional testing and maintains student engagement without the performance barriers

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typically associated with immersive technologies. This approach is consistent with research showing that, for AR to be an effective health education medium in underserved areas, it must be optimised to bridge the digital divide [31]. Overall, the study provides empirical evidence that AR can serve as an effective medium for health education, particularly in addressing early smoking behaviour among children. The results also highlight the importance of combining pedagogical design models with emerging technologies to create impactful learning experiences.

CONCLUSION

The AR-based Magic Card application developed in this study successfully enhances anti-smoking awareness among elementary students. Through interactive 3D visualisations, narrative explanations, and gamified quizzes, the application provides an engaging learning experience that significantly improves students' understanding of smoking-related health risks. Functional testing confirms the system's stability, while N-Gain analysis categorises its educational impact as highly effective within the observed cohort, though these baseline outcomes warrant validation through broader comparative control trials. Despite its strengths, the application is constrained by marker dependence and file size, which may hinder widespread adoption. Future research should explore markerless AR, cloud-based asset streaming, and adaptive interfaces tailored to different age groups. Nonetheless, this study demonstrates the potential of AR as a transformative tool for health education in primary schools, particularly in underserved regions such as Papua. This study acknowledges several limitations, including the small pilot sample size ($N = 9$), the lack of a control group, and technical reliance on physical markers and file size (148 MB). Future research should conduct quasi-experimental studies with larger sample sizes and control groups, while exploring markerless AR and cloud streaming to improve accessibility.

DECLARATION OF AI USE

The authors declare that generative artificial intelligence (AI) tools were used in the preparation of this manuscript. Claude (Anthropic) and Grammarly was used to assist with condensing the abstract, and English language editing. The authors reviewed and revised all AI-assisted content and take full responsibility for the accuracy, originality, and final content of this manuscript.

AUTHOR CONTRIBUTIONS

This journal uses the Contributor Roles Taxonomy (CRediT) to identify individual author contributions to the research and manuscript preparation.

Author	Contribution Roles
Christine H Sinaga	Software, Investigation, Data Curation, Writing – Original Draft.
Remuz Kmurawak	Conceptualization, Methodology, Supervision, Writing – Review & Editing.
Agung Dwi Saputro	Formal Analysis, Validation, Visualization.
Mingsep Rante Sampebua	Resources, Project Administration.
Yokelin Tokoro	Investigation, Writing – Review & Editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest related to the research, writing, or publication of this article.

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