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Original Research

Smart Virtual Reality–Artificial Intelligence for Improving Vulva Hygiene Knowledge and Attitudes among Early Adolescents Girls

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ABSTRACT

Vulva hygiene is a crucial yet often overlooked aspect of adolescent reproductive health, and early adolescents often lack engaging and effective educational media. Smart Virtual Reality–Artificial Intelligence (VR–AI) based education provides an immersive and personalized learning experience, which has the potential to improve health literacy more effectively than conventional approaches. This study aimed to evaluate the effectiveness of VR–AI–based education in improving knowledge and attitudes related to vulva hygiene among early adolescent girls. A quasi-experimental nonequivalent pretest–posttest control group design was conducted at a public elementary school in Purwakarta, Indonesia, involving 35 female students aged 10–13 years, divided into intervention (n=18) and control (n=17) groups. The intervention group received a 3-minute VR–AI educational video via VR headsets, while the control group received a conventional lecture with equivalent duration and content. Knowledge and attitudes were measured using validated questionnaires and analyzed with parametric and nonparametric tests at a significance level of α=0.05. Both groups experienced significant improvements in knowledge (intervention: $p<0.001$; control: $p=0.003$) and attitudes (intervention: $p=0.001$; control: $p=0.010$). Post-test attitudes were significantly higher in the intervention group compared with the control group ($p=0.014$), although knowledge did not differ significantly ($p=0.075$). VR–AI–based education enhances positive attitudes and represents a beneficial approach to adolescent reproductive health promotion. Schools are encouraged to integrate VR–AI media as a complementary strategy to strengthen the effectiveness and long-term sustainability of health education programs.

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INTRODUCTION

Reproductive health and external genital (intimate organ) hygiene are essential for the well-being of adolescent girls. However, many adolescents still face limited access to accurate and comprehensive Sexual and Reproductive Health (SRH) information and services, resulting in an increased risk of health problems, including poor menstrual and vulvar hygiene practices (Okyere et al., 2024; Nkrumah

et al., 2024; Aziz et al., 2024).

According to the World Health Organization (WHO), the highest prevalence of reproductive tract infections occurs in adolescents and young adults (35–42%), while in Indonesia, there are around 63 million adolescents who are at risk of experiencing poor menstrual hygiene practices (Djaguna et al., 2024). Socio-cultural barriers, stigma, and limited parent–adolescent communication further restrict open discussion about reproductive health issues (Klu et al., 2023).

Previous studies have shown that adolescents' reproductive health knowledge remains limited and is often confined to puberty-related changes or menstruation, while other important aspects, such as vulva hygiene, receive little attention (Sinombor, 2023). This gap is even more pronounced in rural settings, where access to information, health services, and educational facilities is more limited than in urban areas (Aziz et al., 2024). These conditions highlight the need for more engaging and interactive educational approaches, as conventional methods such as lectures or posters tend to be passive and less appealing to adolescent (Suttor et al., 2024).

The integration of immersive technologies, such as virtual reality (VR) and artificial intelligence (AI), offers a potential solution to these challenges. VR has been shown to enhance emotional engagement, comprehension, and knowledge retention in health education, while AI enables personalized and adaptive learning experiences based on individual needs (Giovanelli et al., 2023; Brisson et al., 2023). However, empirical evidence on the effectiveness of AI-based VR interventions for vulva hygiene education among adolescent girls remains limited, particularly in low-resource or rural contexts (Radovic & Badawy, 2020).

Based on this gap, this research was conducted in a public elementary school in the rural area of Purwakarta which has limited access to information and technology. A preliminary assessment involving 10 female students revealed varying levels of knowledge regarding vulva hygiene, ranging from low to high categories. Therefore, this study aims to answer the question: "Is AI-based VR video media effective in improving adolescents' knowledge and attitudes toward vulva hygiene?"

METHOD

This study employed a quantitative approach using a quasi-experimental nonequivalent pretest–posttest control group design. Two groups (intervention and control) received both pretest and posttest assessments, without full randomization due to the fixed classroom structure within the school setting. This design was selected to enable systematic comparison between groups while maintaining a natural educational environment.

This research was carried out from July to August 2025 at a public elementary school in Purwakarta. The study population comprised female students aged 10–13 years enrolled in grades 4–6 ($n = 35$). Given the relatively small population size, total sampling was applied. Participants were assigned to the intervention group ($n = 18$) or control group ($n = 17$). Group assignment was performed using the Randomizer.org application, with stratification based on age and grade level to ensure balanced distribution. Baseline characteristic analysis confirmed no statistically significant differences between groups. The sample size met the minimum requirement for quasi-experimental studies (Fraenkel et al., 2012).

The inclusion criteria include students in the age range of 10–13 (based on initial identity data) who are willing to participate in the entire research process and obtain permission from the school. Meanwhile, the exclusion criteria include visual impairment or severe cognitive impairment, absence during tests or interventions, and not filling out a complete questionnaire during the pretest or posttest.

This study involved one independent variable, namely AI-generated VR video–based health education, and two dependent variables, namely knowledge and attitudes regarding vulva hygiene. Data were collected using a knowledge questionnaire consisting of 20 dichotomous items and an attitude questionnaire comprising 14 items measured on a 4-point Likert scale. The instrument was adapted from Marlissa (2017) and demonstrated acceptable validity ($r > 0.5$) and reliability ($\alpha = 0.76$ for knowledge; $\alpha = 0.77$ for attitude). The content validity assessment was performed by two experts with experience in community health education and health technology implementation. They reviewed the instrument and educational media to ensure clarity, relevance, and appropriateness for early adolescents.

Educational media is developed using AI-generated VR videos. The manufacturing process is carried out through several stages: (1) preparation of the manuscript according to indicators of knowledge and vulva hygiene attitudes, (2) character and background animation creation with an AI video generator (Veo 3 and Canva), (3) integration into a 360° VR format, and (4) expert content validation. The VR device used in this study was a commercially available Smart VR headset (Shinecon 10.0), purchased specifically for research purposes.

The intervention procedure began with pretest administration in both groups. Subsequently, the intervention group received health education through a 3-minute AI-generated VR video, presented in a child-friendly cartoon format focusing on vulva hygiene practices. Participants viewed the video individually using VR headsets in a quiet classroom under researchers' supervision. In contrast, the control group received a conventional lecture of equivalent duration (3 minutes) covering the same educational content. Following the intervention, posttests were administered to both groups using the same instruments. All study procedures (pretest, intervention, and

posttest) were conducted in a single session on the same day, with a total duration of approximately 60 minutes. The study flow is illustrated in Figure 1.

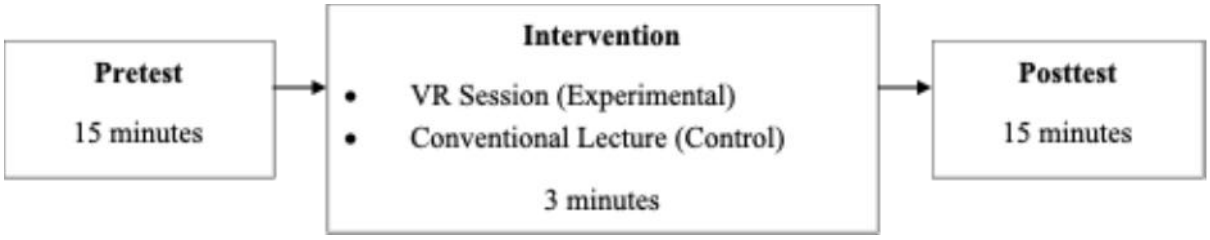

Fig. 1. Research design flowchart with activity duration

Data analysis was carried out using SPSS software version 29. Normality was assessed using the Shapiro–Wilk test. Paired and independent t-tests were applied for normally distributed data, whereas Wilcoxon signed-rank and Mann–Whitney U tests were used for non-normally distributed data. The significance level was set at α=0.05. Knowledge scores are converted to a scale of 0–100 and categorized as High (76–100), Moderate (56–75), Low (40–55), and Very Low (<40). Attitudes are categorized as Positive if the total score of the respondents ≥ the average score, and Negative if the < the average score. Because the participants were minors, written informed consent was obtained from parents or guardians, and verbal assent was obtained from the students prior to data collection. Ethical approval was granted by the Research Ethics Committee of Jenderal Achmad Yani University (No. 057/KEPK/FITKes-Unjani/VII/2025).

RESULT

Table 1. Baseline Characteristics of Respondents in Intervention and Control Groups

Category	Intervention		Control	
	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)
Age (Years)				
10-11	17	94.4	15	88.2
12-13	1	5.6	2	11.8
Grade				
4	2	11.1	4	23.5
5	9	50	6	35.3
6	7	38.9	7	41.2
Resources				
No Information Yet	18	100	17	100
Parent/Teacher/Others	0	0	0	0

Based on Table 1, the majority of respondents in both the intervention and control groups were aged 10–11 years. In the intervention group, most participants were enrolled in grade 5 (50.0%), followed by grade 6 (38.9%) and grade 4 (11.1%). In the control group, 23.5% of participants were from grade 4, 35.3% from grade 5, and 41.2% from grade 6.

Table 2. Level of Knowledge about vulva hygiene (n=35)

Group	Category	Pretest n (%)	Posttest n (%)
Intervention	Good	9 (50.0)	15 (83.3)
	Moderate	6 (33.3)	3 (16.7)
	Low	3 (16.7)	0 (0.0)
	Very Low	0 (0.0)	0 (0.0)
Control	Good	6 (35.3)	8 (47.0)
	Moderate	6 (35.3)	9 (53.0)
	Low	5 (29.4)	0 (0.0)
	Very Low	0 (0.0)	0 (0.0)

As presented in Table 2, the proportion of students with good knowledge in the intervention group increased markedly, from 50.0% at pretest to 83.3% at posttest. In contrast, the control group showed a more modest increase, from 35.3% to 47.0%. No participants in either group remained in the "very low" knowledge category at posttest.

Table 3. Level of Attitude about vulva hygiene (n=35)

Group	Category	Pretest n (%)	Posttest n (%)
Intervention	Positive	9 (50.0)	11 (61.1)
	Negative	9 (50.0)	7 (38.9)
Control	Positive	7 (41.2)	8 (47.1)
	Negative	10 (58.8)	9 (52.9)

Table 3 shows an improvement in attitude scores in both groups following the intervention. In the intervention group, the proportion of participants with a positive attitude increased from 50.0% at pretest to 61.1% at posttest. Similarly, the control group showed a slight increase, from 41.2% to 47.1%. Although improvements were observed in both groups, the increase was greater in the intervention group.

Table 4. Comparison of Knowledge and Attitude Scores on Vulva Hygiene Before and After Intervention (n=35)

Variable	Group	Pretest (Mean ± SD)	Posttest (Mean ± SD)	95% CI of mean difference	*p*-value (within group)	*p*-value (between groups, posttest)
Knowledge	Intervention	15.00 ± 2.59	17.50 ± 2.57	-	<0.001	0.075
	Control	14.18 ± 3.34	15.76 ± 2.73	-	0.003	
Attitude	Intervention	44.33 ± 7.16	48.61 ± 6.45	1.991 – 6.565	0.001	0.014
	Control	40.65 ± 6.73	42.88 ± 6.65	0.614 – 3.856	0.010	

Note: *p*-values for within-group comparisons were obtained using the Wilcoxon signed-rank test for knowledge and the paired *t*-test for attitude. Between-group posttest comparisons were analyzed using the Mann–Whitney *U* test for knowledge and the independent *t*-test for attitude.

Table 4 shows both groups' pretest and posttest scores of knowledges and attitude. Knowledge scores significantly increased after the intervention in both the intervention ($p < 0.001$) and control ($p = 0.003$) groups, although the between-group difference in posttest knowledge was not significant ($p = 0.075$).

For attitudes, significant improvements were observed in both groups ($p = 0.001$; $p = 0.010$), with posttest scores significantly higher in the intervention group ($p = 0.014$), indicating the effectiveness of VR-AI education. Figures 2 and 3 further illustrate participants' active engagement during the immersive VR-AI sessions.

Fig. 2. A student using a virtual reality (VR) headset during the AI-based vulva hygiene educational intervention

Fig. 3. Side-angle view of a student using a virtual reality (VR) headset

DISCUSSION

Interpretation of Key Findings

This study found that the Smart VR–AI intervention yielded differential effects on early adolescents' knowledge and attitudes regarding vulvar hygiene. For knowledge, the Wilcoxon test showed significant improvements in both the intervention ($p < 0.001$) and control ($p = 0.003$) groups. However, the Mann–Whitney U test revealed no significant difference between groups ($p = 0.075$), indicating that knowledge gains achieved through Smart VR–AI were not significantly greater than those obtained through conventional lectures. This finding may be explained by the effectiveness of traditional instruction or the presence of a testing or exposure effect, whereby repeated measurement enhances memory and awareness (Yang et al., 2019).

In contrast, attitude-related findings demonstrated a stronger impact of the Smart VR-AI intervention. The paired t-test showed significant improvements in attitudes in both the intervention ($p = 0.001$) and control ($p = 0.010$) groups, while the independent t-test identified a significant difference between them ($p = 0.014$). These results indicate that the VR–AI intervention produced significantly greater positive changes in attitudes compared with the control condition. The immersive and interactive nature of VR, combined with AI-driven personalization, likely enhanced emotional engagement, contextual understanding, and the internalization of health-promoting attitudes more effectively than conventional lectures (Yang et al., 2019; Budnarowski et al., 2025).

Overall, this study demonstrated significant improvements in both knowledge and attitudes within each group. However, between-group were observed only for attitudes, with the intervention group showing greater gains. This suggests that VR–AI–based education is particularly effective in shaping adolescents' attitudes toward vulvar hygiene, while its additional effect on knowledge, although evident, may be less pronounced in the short term when compared with conventional teaching methods (Park et al., 2023).

Comparison with Previous Studies

These findings are consistent with a growing body of evidence supporting the effectiveness of digital and immersive media in adolescent health education. Previous studies have reported that audiovisual and video-based learning significantly improves reproductive health knowledge and attitudes (Wahyudi & Raharjo, 2023). Moreover, systematic reviews indicate that virtual reality enhances not only knowledge but also positive behavioral change, with a reported standard mean difference of 0.57 (Park et al., 2023).

This study further supports these findings by demonstrating significant knowledge gains in both the intervention and control groups, underscoring the role of repeated exposure to educational content (Yang et al., 2019). The "test effect," in which completing a pre-intervention questionnaire enhances attention and memory, may have contributed to these results (Muhlisa et al., 2023; Yang et al., 2019). Additionally, participation in health-related surveys can heighten self-awareness and engagement, thereby improving information retention (Muhlisa et al., 2023). This mechanism may explain why, despite significant within-group gains, the between-group difference in knowledge was not statistically significant (p = 0.075).

Conversely, the stronger effects observed for attitudes align with prior evidence that VR interventions are particularly effective in influencing affective outcomes (Efendi et al., 2023). Immersive experiences facilitate emotional engagement and enable learners to visualize the consequences of health behaviors, which is often less achievable through traditional instructional methods (Andalib & Monsur, 2024; Lacle-Melendez et al., 2025) Such engagement is especially important in health promotion, where changing attitudes is frequently more challenging than increasing knowledge (Requero et al., 2020).

Previous research has shown that VR-based environments enhance emotional engagement, leading to more positive attitudes and stronger behavioral intentions (Nguyen, 2025). Meta-analyses further confirm that VR enhances satisfaction, confidence, and affective learning outcomes (Sung et al., 2024), and is more effective at shifting social attitudes than non-immersive approaches (Nikolaou et al., 2022).

In reproductive health education, VR interventions have demonstrated significantly greater improvements in adolescent attitudes compared with conventional methods, findings that are consistent with the present study (p = 0.014) (Sung et al., 2024). Comparable outcomes have been observed in other fields, such as environmental education, where immersive experiences enhance empathy and attitude change (Xie & Yang, 2025). Collectively, these findings indicate that the VR–AI intervention effectively promoted positive attitudes toward vulvar hygiene.

Notably, the integration of artificial intelligence into VR represents an advancement beyond conventional virtual simulations. AI-driven personalization and adaptive narratives increase content relevance, thereby strengthening attitude change (Ding, 2025). This suggests that VR–AI–based interventions may offer a novel and promising approach to adolescent health education, with greater potential for sustained behavioral impact than traditional methods (Rowe & Lester, 2020).

Possible Explanations and Mechanisms

The divergence between knowledge and attitude outcomes in this study can be explained by several theoretical and contextual mechanisms. Regarding knowledge, although both groups showed significant improvement, the absence of a statistically significant difference between the intervention and control groups (p = 0.075) may be attributed to testing effects and heightened self-awareness resulting from participation in health surveys (Yang et al., 2019). From a cognitive psychology perspective, repeated measurement enhances familiarity with content, thereby strengthening memory and comprehension even in the absence of targeted interventions (Cowan et al., 2024). Additionally, participants in the control group may have received supplementary information from teachers, peers, or prior learning experiences, which could independently contribute to knowledge gains beyond the Smart VR–AI program.

In contrast, the significant improvement in attitudes observed in the intervention group (p = 0.014) underscores the unique advantages of immersive learning. VR creates a strong sense of presence, enabling adolescents to engage with realistic scenarios that activate cognitive, affective, and social processes simultaneously (Arts et al., 2025). This aligns with the Cognitive-Affective Theory of Learning with Media (CATLM), which posits that multimedia experiences integrating visual, auditory, and emotional stimuli facilitate deeper learning and more enduring attitudinal change (Ozcelik & Arslan-Ari, 2024). Moreover, Smart VR-AI's adaptive and personalized content enhances relevance to learners' developmental stages, thereby deepening emotional engagement and strengthening the internalization of positive attitudes toward vulvar hygiene (Ding, 2025; Rowe & Lester, 2020).

This approach is particularly impactful during early adolescence (ages 10–13), a critical period for shaping lifelong health-related attitudes, as individuals in this stage are highly receptive to interactive and experiential learning (Mancone et al., 2024). The novelty and immersive qualities of VR-AI not only heighten curiosity but also encourage preference for experiential learning, making this method more effective than conventional approaches (Andalib & Monsur, 2024). These findings suggest that while knowledge acquisition can occur through both traditional and digital methods, affective outcomes, particularly attitudes, are more effectively enhanced through immersive, interactive, and personalized approaches such as VR AI (Xie & Yang, 2025).

Strengths, Limitations, and Implications

This study offers several noteworthy strengths. It introduces an innovative educational approach by integrating virtual reality and artificial intelligence to address vulvar hygiene in early adolescence, an area often overlooked in elementary-level reproductive health education (Ding, 2025). It also examines both cognitive (knowledge)

and affective (attitude) outcomes, providing a more comprehensive understanding of the intervention's impact (Ibrahim et al., 2024). The use of a quasi-experimental design with intervention and control groups also strengthens internal validity and supports cautious causal interpretation (Ibrahim et al., 2024).

However, some limitations should be acknowledged. The relatively small sample size (n = 35) and single-school setting limit the generalizability of the findings (Akollo, 2024). The short duration of follow-up restricts conclusions regarding the long-term sustainability of changes in knowledge and attitudes (Isenaj et al., 2025). Moreverr, the use of self-administered questionnaires may introduce social desirability bias, and the significant improvements observed in the control group suggest the influence of external factors such as family discussions, extracurricular exposure, or peer interactions beyond the researchers' control (Isenaj et al., 2025; Pakarinen et al., 2020).

Despite these limitations, the findings offer important implications for practice and future research. VR–AI demonstrates strong potential as a scalable tool for school-based health education, particularly for sensitive topics that are difficult to convey effectively through traditional approaches (Heru et al., 2023). Its pronounced effect on attitudes highlights its promise for supporting sustained behavioral change among adolescents (Rowe & Lester, 2020). Future studies should involve larger and more diverse samples, longitudinal designs, and mixed method approaches to explore long-term effects and learner experiences. Further investigation into curricular integration and cost-effectiveness would also provide valuable insights for educators and policymakers seeking to modernize adolescent health education.

CONCLUSION

This study demonstrates that Smart Virtual Reality–Artificial Intelligence (VR–AI)–based interventions are effective in improving early adolescents' knowledge and attitudes regarding vulvar hygiene. Although knowledge scores increased significantly in both the intervention and control groups, the absence of a significant between-group difference suggests that conventional education and repeated testing effects may have contributed to cognitive gains. In contrast, the significantly greater improvement in attitudes observed in the intervention group indicates that VR–AI is particularly effective in facilitating affective learning and fostering positive health-related attitudes.

These findings underscore the potential of VR–AI as an innovative and engaging educational tool for reproductive health, particularly for sensitive topics that are often inadequately addressed through conventional instructional approaches. Further studies involving larger and more diverse samples, longer follow-up periods, and curricular integration are recommended to confirm the long-term effectiveness and scalability of VR–AI–based health education.

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