TEACHER READINESS FOR AUGMENTED-REALITY HEALTH EDUCATION IN ELEMENTARY PHYSICAL EDUCATION: A COMMUNITY-ENGAGED EVALUATION OF THE BIPINIPAR INTERACTIVE BOOK IN SURABAYA

Junaidi Budi Prihantono[1]*, Dwi Lorry Juniarisca[2], Arifah Kaharina[3], Aby Nugrah Septanto[4], Novadri Ayubi[5]

[1-5]Program Studi Pendidikan Jasmani, Kesehatan, dan Rekreasi, Fakultas Ilmu Keolahragaan dan Kesehatan, Universitas Negeri Surabaya

Email Korespodensi: junaidibudi@unesa.ac.id

Corresponding Author: dwijuniarisca@unesa.ac.id

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ABSTRACT

Elementary physical education must translate abstract health messages about hygiene, physical activity, safety, and healthy living into concrete learning experiences. This community-engaged study evaluated BIPINIPAR, an augmented-reality interactive health-education book for Indonesian elementary Physical Education, Sport, and Health (PJOK), by examining changes in teacher readiness and perceived implementation feasibility. A one-group pre–post evaluation was conducted with 44 valid responses from elementary-school physical education teachers or education practitioners in Surabaya. Five readiness indicators were rated before and after training. Because one baseline item used a shorter scale than its paired post-training item, all readiness indicators were min–max normalized to a 0–100 metric. Program appraisal was measured with nine 1–5 items, and open-ended comments were coded thematically. Overall readiness increased from 86.14 ± 18.03 to 91.21 ± 11.94, with a mean gain of 5.08 percentage points (95% CI 1.14–9.01; p = .013; Cohen's dz = 0.39). Gains were strongest for AR-book knowledge, AR-use skill, and confidence to teach with AR. Program appraisal was very high (mean 4.81/5), with 99.5% of item-level responses in the high or very high range. BIPINIPAR is best understood as a teacher-mediated implementation-readiness intervention that can support AR-enhanced physical education, health education when accompanied by pedagogical training and sustained classroom support.

Keywords: Augmented Reality, Interactive Health Education Book, Elementary Physical Education, Teacher Readiness, Community-Engaged Learning.

1. BACKGROUND

Elementary Physical Education, Sport, and Health (PJOK) occupies a distinctive position in basic education because it develops bodily competence while introducing children to foundational health practices. In Indonesia, as in many school systems, PJOK teachers are expected to connect movement, hygiene, nutrition, safety, physical activity, and healthy lifestyle messages within lessons that are often short, crowded, and practice-oriented. This dual mandate is pedagogically demanding because health education frequently concerns invisible processes, such as germ transmission, physiological response to exercise, or the consequences of unsafe habits. Studies on AR in physical education suggest that digitally enriched instruction can support motor-skill and motivation outcomes when it is used to complement, rather than replace, physical practice (Chang et al., 2020; Liang et al., 2023; Ridwan et al., 2025). The central problem is therefore not whether technology is attractive, but whether it helps teachers translate abstract health content into concrete learning experiences.

Augmented reality is a promising response to this problem because it overlays digital visualizations onto real-world materials. Reviews and bibliometric analyses show that AR has expanded rapidly in education, with recurrent claims about engagement, conceptual visualization, motivation, and performance (Altinpulluk, 2019; Altinpulluk & Yildirim, 2023; Arshad et al., 2024). A recent meta-analysis also reported an overall positive effect of AR on student performance, while noting that benefits vary by subject, implementation quality, and learner characteristics (Adi et al., 2025). These findings justify cautious experimentation with AR in elementary physical education, where visualized health concepts may be especially valuable. At the same time, state-of-the-art reviews warn that adoption must be supported by appropriate curriculum integration, teacher training, and robust evaluation rather than by technological enthusiasm alone (Alhebaishi & Stone, 2024; Anselmo et al., 2024).

2. RESEARCH PROBLEMS AND QUESTIONS

In the Surabaya elementary-school physical education context, the immediate implementation problem was not the availability of an attractive AR product alone, but whether teachers could understand, operate, and pedagogically translate BIPINIPAR into classroom health-education routines. The program was therefore evaluated as a readiness-building intervention for teachers rather than as a direct student-achievement trial.

The present study responds to three gaps. First, relatively few studies examine AR-based interactive books as media for health education within elementary physical education. Second, community-engagement programs often document activity completion but provide limited empirical evidence linking baseline capacity, training, readiness change, feasibility, and participant feedback. Third, many AR education studies center student outcomes while under-specifying the teacher development pathway required for adoption. The novelty of this study lies in evaluating BIPINIPAR not as a finished effectiveness intervention for pupils, but as an implementation-readiness intervention for physical education teachers. This framing is intentionally cautious and empirically aligned with the available dataset.

The study was guided by three research questions. First, to what extent did participant readiness to use AR-based health education increase after the BIPINIPAR training? Second, how did participants evaluate the relevance, clarity, usability, perceived student benefit, and overall quality of the program? Third, what implementation lessons emerged from open-ended comments? By answering these questions, the manuscript contributes a proximal-outcome model for community-engaged AR innovation: a classroom medium becomes educationally meaningful when it improves teacher readiness, is perceived as feasible, and generates actionable feedback for classroom translation.

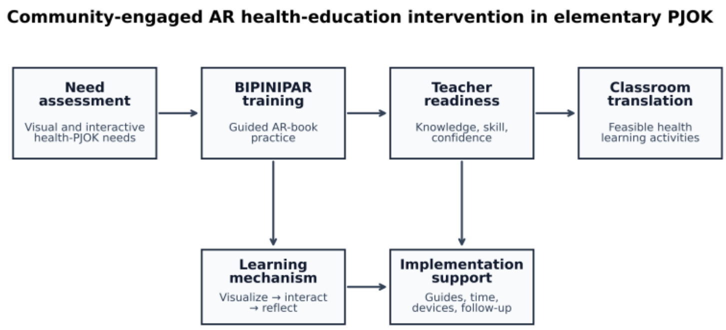

Figure 1. Conceptual model of the community-engaged AR health-education book intervention. The model positions BIPINIPAR as a teacher-mediated bridge between school needs, AR-book training, readiness development, and classroom translation.

3. LITERATURE REVIEW

Evidence from early-childhood and primary-school research is particularly relevant for BIPINIPAR. Systematic evidence in preschool education indicates that AR has been used through 2D and 3D objects, animations, images, and models, with reported benefits for interest and attention but continuing concerns about access, cost, and screen time (Adeyele, 2025). Studies with primary pupils likewise report improvements in engagement, self-efficacy, motivation, and learning outcomes when AR is aligned with age-appropriate tasks and meaningful content (Abinaya & Vadivu, 2023; Aldeeb et al., 2024; AlAli & Al-Barakat, 2024). Indonesian evidence is also emerging: AR in elementary cultural education improved cultural awareness, literacy, and engagement, although teacher-reported technical challenges remained important (Andayani et al., 2026), while Indonesian elementary studies on AR-based learning media emphasize motivation, contextual learning, and local relevance (Herwin et al., 2023; Ningsih, 2025; Novianti et al., 2026).

The interactive-book format is a particularly appropriate bridge between printed school materials and immersive media. Research on AR graphic books and storybooks suggests that printed narratives or pages can become more concrete when learners view 3D objects, animations, or digital overlays linked to the page (Du et al., 2024; Hung et al., 2017). AR digital picture books have also been investigated as tools for supporting attention, motivation, and emotional regulation in children (Yang et al., 2026). These studies matter because BIPINIPAR is not a stand-alone application; it is a book-based medium in which the printed page remains the organizing structure and AR functions as an explanatory layer. In elementary physical education, such a hybrid medium may reduce the practical barrier of moving from familiar book-based teaching to fully digital learning.

From a learning-design perspective, the value of AR for elementary learners is closely tied to multimodality. Children often benefit when a concept is represented through text, image, movement, and interaction rather than through verbal instruction alone. Primary-school AR studies on geometry and natural-social science show that AR can support conceptual understanding when digital visualization is paired with clear instructional sequencing (Na et al., 2025; Tarng et al., 2024; Tiep & Huong, 2025). Movement-based learning research in early childhood further indicates that young learners benefit from multimodal stations and purposeful activity design rather than passive exposure to digital materials (Aloizou et al., 2025). For PJOK, this is especially relevant: the subject naturally combines body movement, visual cues, peer interaction, and reflective explanation.

This pedagogical framing also guards against a common misunderstanding of AR. AR should not be added to a lesson simply because it is novel. Primary-school research on generative learning strategies suggests that adding reflective actions such as self-explanation or self-testing does not necessarily diminish students' attitudes toward AR, and may help position the technology as a learning resource rather than entertainment (Buchner, 2022). Similarly, studies of AR formative assessment show that AR can be used as part of feedback and assessment processes, not only as a presentation medium (Bhagat et al., 2019). In the present study, this insight justifies the focus on teacher readiness: teachers need to understand not only how to open the AR object, but also how to ask, assess, and connect it to the physical education objective.

However, research also shows that AR does not automatically improve learning. A randomized study found that mobile AR enhanced engagement without producing superior learning outcomes, thereby highlighting the need to design AR experiences according to instructional principles rather than novelty (Bhat et al., 2025). A meta-analysis in anatomy education similarly concluded that evidence for AR effects was inconsistent and that more rigorous trials were needed (Bölek et al., 2021). Studies of AR motivation and engagement further suggest that the value of AR is mediated by attention, relevance, confidence, satisfaction, scaffolding, feedback, usability, and perceived control (Bacca et al., 2018; Baabdullah et al., 2022; Bhagat et al., 2021; Nikou, 2026). Consequently, the central research problem should be framed as implementation readiness: can teachers understand, use, and pedagogically integrate the AR medium in their classroom routines?

Teacher readiness is the most defensible proximal outcome for an initial community-engagement evaluation. Research on teachers' perceptions indicates that educators may recognize AR's pedagogical potential while reporting lower technical competence, making continuous professional development essential (Piedade & Batista, 2025). Studies of school teachers and pre-service teachers likewise identify prior exposure, training, confidence, access, technical support, and usability as critical factors in AR adoption (Al Buraiki et al., 2025; Punar Özçelik et al., 2025; Salmaini et al., 2025). Broader research on educator digital integration shows that professional development can increase knowledge, confidence, and practical application, but that resource limitations and time constraints remain barriers (Abildinova et al., 2024). For a physical education innovation such as BIPINIPAR, teacher readiness is not a secondary issue; it is the mechanism through which the medium can later influence pupils.

Health education adds another layer to this argument. Immersive technologies have been explored in school-based health promotion because they can situate learners in realistic scenarios, stimulate discussion, and make consequences visible (Jiang et al., 2026). AR board-game studies in health education also show that AR can be combined with gamified classroom resources to influence outcomes, emotions, motivation, and acceptance (Lin et al., 2020; Lin et al., 2021). Health-professions reviews similarly emphasize that AR, VR, and MR interventions require theoretical and instructional design grounding if they are to produce more than short-term novelty effects (Asoodar et al., 2024). These findings support the conceptualization of BIPINIPAR as a teacher-mediated, pedagogically guided, AR-enhanced health-education tool.

4. METHODOLOGY

This study used a one-group pre-post community-engagement evaluation design. The object of evaluation was the implementation training for BIPINIPAR, an augmented-reality interactive book developed to support health education in elementary physical education. The design was appropriate for a first-stage service-based study because the primary question was whether structured exposure to the medium was associated with immediate changes in participant readiness and perceived classroom feasibility. Similar pre-post and mixed evaluation logics are common in early implementation studies of digital integration and immersive education, particularly when the purpose is to assess readiness, usability, perceived benefit, or proximal learning outcomes before conducting a controlled effectiveness trial (Abildinova et al., 2024; Asoodar et al., 2024; Punar Özçelik et al., 2025).

The dataset consisted of 44 valid responses recorded in the activity evaluation spreadsheet. The response sheet included event information, participant identity fields, school affiliation, pre-training ratings, post-training ratings, program appraisal items, and open-ended comments. Personal identifying information was excluded from the analysis and from this manuscript. School names showed spelling variation and repeated entries; consequently, the analysis treated the data as participant-level responses rather than using school-level clustering. The activity was held in an auditorium setting at the Faculty of Sports and Health Sciences, Universitas Negeri Surabaya. Participants were elementary-school physical education teachers or education practitioners associated with elementary schools in Surabaya.

The evaluation was conceptualized around a simple theory of change. The training would first expose participants to the rationale for AR-mediated health education. It would then demonstrate the BIPINIPAR book and allow participants to imagine or practise its use. This exposure was expected to increase technology-specific knowledge and skills, strengthen confidence, and generate perceptions of classroom feasibility. The program appraisal items served as implementation indicators because perceived relevance, clarity, usability, time allocation, and student benefit are practical conditions for adoption. This theory of change follows the broader educational technology literature, in which successful integration depends on perceived value, usability, support, and alignment with teaching routines (Baabdullah et al., 2022; Piedade & Batista, 2025).

Ethical handling of the dataset was based on minimization. The evaluation sheet contained names, schools, and contact information, but these variables were not used analytically. The manuscript reports only aggregate statistics and de-identified thematic findings. Because the study evaluates a community-engagement training activity rather than a clinical intervention, the most important ethical risks concerned privacy, accurate representation of participant feedback, and avoidance of overstated claims. The analysis therefore separates evidence of teacher readiness from unmeasured student outcomes and presents limitations explicitly.

The intervention introduced participants to the educational role of health content in physical education and to the use of BIPINIPAR as an AR-based book medium. The training logic combined conceptual orientation, demonstration, guided exploration, and reflection on classroom use. BIPINIPAR was presented as a medium for helping teachers explain health topics through interactive visual content rather than relying solely on verbal explanation or static textbook images. This implementation logic is consistent with AR research emphasizing the importance of scaffolding, real-time feedback, relevance, and confidence in motivational learning experiences (Bacca et al., 2018; Bhagat et al., 2021). It also reflects the wider finding that educator training is necessary because perceived usefulness alone does not guarantee classroom adoption (Al Buraiki et al., 2025; Piedade & Batista, 2025; Salmaini et al., 2025).

The evaluation instrument contained four major parts. The first part captured event and participant information. The second part measured readiness before training through five indicators: understanding of the importance of health education in physical education, knowledge of AR interactive books, skill in using AR technology for learning, confidence to teach physical education using interactive AR media, and ability to apply health education material in the classroom. The third part repeated the same five constructs after training. Most readiness items used a seven-point scale from very low to very high. One before-training item on ability to apply health education used a five-point scale in the form, whereas the corresponding after-training item used seven points. To preserve the paired structure while avoiding raw scale distortion, all readiness items were normalized to a 0-100 metric using min-max transformation before pre-post comparison.

The fourth part measured program appraisal through nine items on a five-point scale: relevance of material to elementary physical education needs, presenter skill, clarity of AR-book use, interaction and participation, appropriateness of time allocation, ease of using the AR book in class, benefit for strengthening students' health-education understanding, use of AR to attract students' learning interest, and overall activity quality. Three open-ended questions captured positive impressions, suggestions for future improvement, and the most interesting material or technology. The comment analysis used pragmatic thematic coding. Because responses were short and service-evaluation oriented, the goal was not to generate a full qualitative theory but to identify recurring implementation signals such as classroom applicability, new professional knowledge, interest in AR/3D media, assessment support, and requests for follow-up.

Quantitative analysis proceeded in five steps. First, descriptive statistics were computed for raw item ratings and normalized readiness scores. Second, internal consistency was estimated using Cronbach's alpha for the baseline readiness items, post-training readiness items, and program appraisal items. Third, paired comparisons were performed on normalized readiness scores, both overall and item-wise. The overall readiness score was calculated as the mean of the five normalized readiness indicators for each participant. Paired t-tests were used to estimate mean change and 95% confidence intervals, while Wilcoxon signed-rank tests were used as a robustness check for ordinal scale structure. Fourth, effect size was reported using Cohen's dz, calculated as the mean paired difference divided by the standard deviation of paired differences. Fifth, program appraisal items were summarized using means, standard deviations, confidence intervals, and the proportion of high or very high ratings.

Table 1. Evaluation architecture, measurement domains, and analytical use

Component	Data/source	Measurement content	Scale/format	Analytical role
Participants and setting	Response spreadsheet	44 valid participant responses from elementary-school physical education/community-training participants in Surabaya; identifiers excluded.	Participant-level responses	Defines empirical sample and implementation context.
Pre-training readiness	Evaluation form section A	Health-education importance, AR-book knowledge, AR-use skill, AR teaching confidence, and application of health education.	Mostly 1-7; one application item 1-5	Baseline readiness profile; normalized to 0-100 for paired analysis.
Post-training readiness	Evaluation form section B	Same five teacher readiness constructs after the training intervention.	1-7 Likert-type ratings	Post-training readiness profile and change estimation.
Program appraisal	Evaluation form activity section	Material relevance, presenter skill, clarity, interaction, time, ease of classroom use, perceived student benefit, student-	1-5 Likert-type ratings	Implementation feasibility and participant acceptance.

		interest value, overall quality.		
Open-ended feedback	Three comment fields	Positive impressions, suggestions for future improvement, and most interesting material or technology.	Short free-text responses	Pragmatic thematic coding to identify implementation signals and improvement needs.

Note. The response form contained identifiable fields; these were not used in the analysis. The scale inconsistency in one baseline item was handled through min-max normalization.

The methodological premise is that teacher readiness is a proximal implementation outcome. It does not prove that students learned more, but it indicates whether teachers moved closer to being able and willing to use the medium in class. This distinction is important because AR research contains both positive and cautionary evidence: some studies report gains in motivation, engagement, and learning, while others show engagement effects without corresponding achievement gains (Adi et al., 2025; Bhat et al., 2025; Bölek et al., 2021). The present manuscript therefore interprets the results as evidence of training-associated readiness and perceived feasibility, not as direct evidence of pupil health-literacy improvement.

Data preparation followed a conservative approach. Names and contact numbers were not used. Numeric response columns were checked for range consistency. The pre-training item concerning application of health education was identified as using a five-point format, whereas the corresponding post-training item used a seven-point format. Rather than deleting the item, the analysis retained it with normalization because the construct was substantively important. Min-max normalization transformed each item score into the proportion of its possible range achieved by the participant, allowing all readiness indicators to be expressed on a common 0-100 metric. This decision is reported transparently because implementation studies should make measurement constraints visible rather than hide them.

5. RESULT AND DISCUSSION

a. Result

The dataset contained 44 valid participant responses. The evaluation form and response structure showed that the program was designed to capture changes before and after exposure to BIPINIPAR, followed by a broader appraisal of the activity. The pre-training profile was already favourable. On the original seven-point items, the mean baseline score was 6.32 for understanding the importance of health education in physical education, 5.98 for knowledge of AR interactive books, 5.98 for skill in using AR technology, and 6.05 for confidence to teach with AR. The baseline item on ability to apply health education used a five-point scale and had a mean of 4.68. These results suggest that participants entered the activity with positive views of physical education health education but with room to strengthen technology-specific knowledge and skills.

After training, all five readiness indicators showed favourable scores. The strongest post-training means were observed for ability to apply health education in class (6.59/7), understanding of health education importance (6.57/7), confidence to teach with AR (6.43/7), knowledge of AR interactive books (6.41/7), and AR-use skill (6.36/7). On normalized 0-100 scores, overall readiness increased from 86.14 ± 18.03 before training to 91.21 ± 11.94 after training. The mean gain was 5.08 percentage points, with a 95% confidence interval from 1.14 to 9.01. The paired t-test indicated a statistically significant change ($t = 2.60$, $p = .013$), and the Wilcoxon signed-rank test yielded a consistent result ($p = .040$). The effect size was small-to-moderate (Cohen's dz = 0.39), which is meaningful given the high baseline scores and the short-term nature of the intervention.

Table 2. Pre-post change in teacher readiness indicators after BIPINIPAR training.

Readiness indicator	Pre-training mean ± SD (%)	Post-training mean ± SD (%)	Mean Δ pp (95% CI)	p	Cohen's dz
Overall readiness composite	86.14 ± 18.03	91.21 ± 11.94	5.08 (1.14 to 9.01)	0.013	0.39
Health education importance	88.64	92.80	4.17 (-0.74 to 9.07)	0.094	0.26
AR-book knowledge	82.95	90.15	7.20 (2.38 to 12.01)	0.004	0.45
AR use skills	82.95	89.39	6.44 (1.91 to 10.97)	0.006	0.43
Confidence to teach with AR	84.09	90.53	6.44 (1.29 to 11.59)	0.015	0.38
Applying health education	92.05	93.18	1.14 (-1.79 to 4.06)	0.437	0.12

Note. Readiness scores were min-max normalized to a 0-100 metric before comparison. Δ pp = percentage-point change. p values are from paired t-tests; the overall Wilcoxon signed-rank robustness check was p = .040. Cronbach's alpha was 0.959 before training, 0.949 after training, and 0.921 for the program appraisal scale.

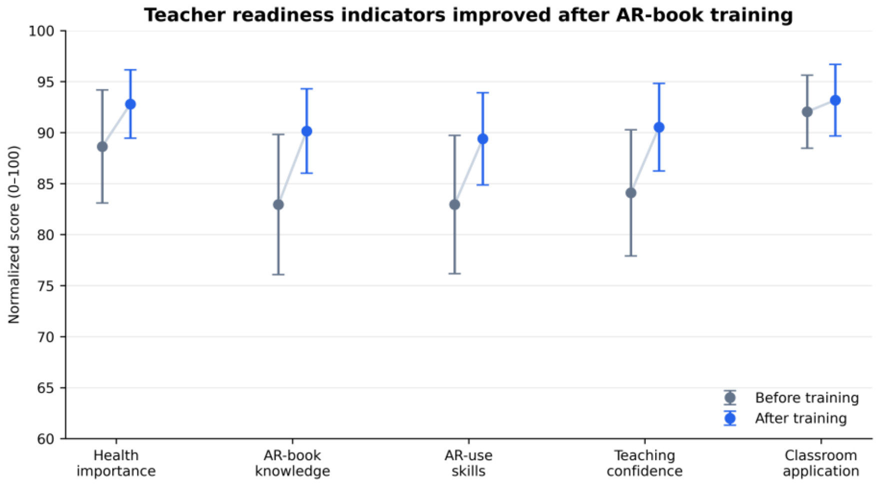

Figure 2. Pre-post readiness profile across five normalized teacher readiness indicators. Error bars show 95% confidence intervals.

Item-level results clarify where the intervention had the clearest effect. Knowledge of AR interactive books increased by 7.20 percentage points on the normalized scale ($p = .004$), while AR-use skills increased by 6.44 percentage points ($p = .006$). Confidence to teach physical education using interactive AR media increased by 6.44 percentage points ($p = .015$). These three outcomes align directly with the technological and pedagogical aims of the training. Understanding of health education importance increased by 4.17 percentage points, but the p value did not reach the conventional threshold ($p = .094$), likely because baseline ratings were already high. Classroom application of health education showed only a small normalized increase of 1.14 percentage points ($p = .437$), again suggesting a ceiling effect and the influence of the baseline scale difference.

Internal consistency was high across the rating constructs. Cronbach's alpha was 0.959 for the baseline readiness scale, 0.949 for the post-training readiness scale, and 0.921 for the program appraisal scale. These values indicate that the items cohered strongly as evaluation dimensions. Although high reliability should not be overinterpreted as evidence of construct validity, it supports the use of composite readiness and appraisal indicators for this initial program evaluation.

Program appraisal results were very positive. The average rating across the nine activity-evaluation items was 4.81 out of 5. The highest mean scores were recorded for presenter skill (4.89/5) and the perceived benefit of the interactive book for strengthening students' understanding of health education (4.89/5). Clarity of AR-book use and overall activity quality reached 4.84/5. Ease of using the AR book in class had the lowest mean among the appraisal indicators, but it was still very high (4.68/5). Across all program appraisal responses, 99.5% of item-level ratings were high or very high. This pattern is important because participants did not merely enjoy the event; they evaluated the content, delivery, clarity, usefulness, and classroom feasibility favourably.

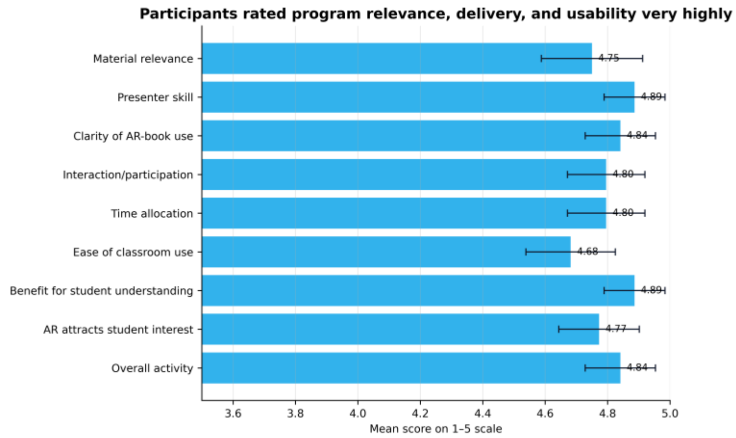

Figure 3. Program appraisal ratings across nine activity-evaluation dimensions on a 1-5 scale. Error bars show 95% confidence intervals.

The open-ended comments provide interpretive depth. Positive impressions most frequently referred to classroom or physical education applicability, new professional knowledge, and relevance for teaching. Participants described the activity as useful for physical education learning, helpful for teachers, applicable in schools, and beneficial for strengthening health education. Several responses emphasized that the program expanded knowledge and provided new experience. Comments also highlighted the appeal of technology, including AR, interactive applications, media in three dimensions, and AI-supported tools. These comments support the quantitative finding that the activity was not experienced as an isolated lecture but as a source of practical pedagogical resources.

Suggestions for improvement were also instructive. The most frequent suggestion was to sustain or repeat the activity through regular follow-up, additional training, or continued collaboration. A second recurring theme was the need for more time, especially for discussion and question-and-answer sessions. Some participants requested deeper content, broader physical education issues, additional media examples, more health material, and technical refinement such as wider access to the application. A smaller set of responses proposed more active formats, including movement-based activities and ice-breaking. These suggestions do not undermine the positive appraisal; rather, they reveal that participants saw the intervention as valuable enough to warrant extension.

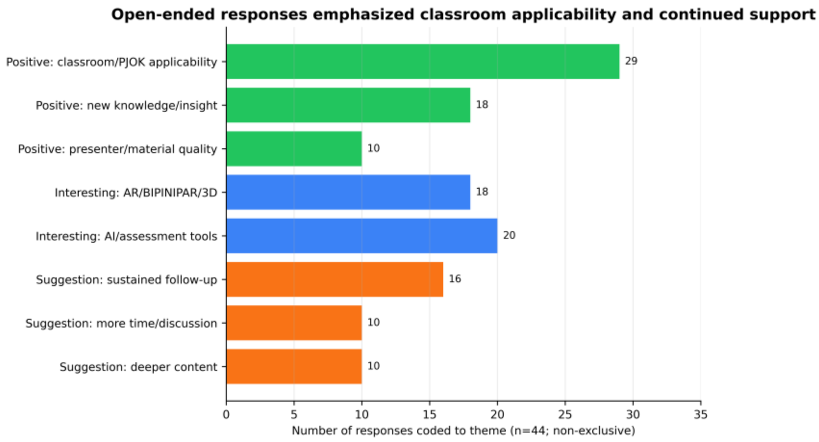

Figure 4. Non-exclusive thematic coding of open-ended responses. Counts indicate the number of responses containing each theme among 44 participants.

The qualitative coding identified four dominant implementation signals. First, many participants connected the activity directly to physical education classroom practice, suggesting that the topic was not perceived as distant from their professional tasks. Second, participants emphasized new knowledge and professional insight, indicating that the program functioned as teacher learning rather than merely product promotion. Third, the AR, 3D, application, and book-based media features were repeatedly identified as interesting, which supports the argument that the medium's visual affordances were salient. Fourth, comments on AI-supported tools and assessment revealed that teachers were interested in a broader digital teaching ecosystem, not only the AR book itself.

The suggestions refine the implementation model. Requests for more time, broader material, longer discussion, and repeated activities indicate that participants viewed the workshop as an introductory cycle. This matters because teacher readiness should not be treated as a one-time result. Readiness can decay if teachers do not have opportunities to practise, adapt, and receive feedback. Conversely, an initial positive response can become sustained adoption if teachers are given classroom scenarios, device-management strategies, and opportunities to share implementation experiences. The data therefore point toward a follow-up model rather than a completed dissemination model.

b. Discussion

The findings support the central thesis that an AR interactive health-education book can function as a feasible teacher-mediated innovation for elementary physical education when implementation begins with teacher readiness. The quantitative evidence demonstrates a statistically significant increase in overall readiness after training, while the qualitative evidence shows that teachers perceived the activity as relevant, useful, and worth continuing. The strongest effects appeared in the domains most directly related to the innovation: knowledge of AR interactive books, skill in using AR technology, and confidence to teach with AR. This pattern mirrors teacher-readiness research showing that educators may be receptive to AR but require structured exposure, technical support, and pedagogical modelling before they can use it confidently (Al Buraiki et al., 2025; Piedade & Batista, 2025; Salmaini et al., 2025).

A key interpretive point is the ceiling effect. Participants entered the activity with high baseline scores, especially for understanding the importance of health education and applying health education in class. This is unsurprising because the respondents were physical education teachers or education practitioners; they were not novices in the broad value of health education. The program therefore did not need to convince them that health matters. Its more important role was to provide a new representational and instructional tool. The gains in AR-specific knowledge and skill indicate that the intervention addressed a technology-pedagogy gap rather than a general motivational deficit. This distinction is consistent with broader professional-development evidence: digital integration improves when teachers receive training that links technology to practical methods and curricular constraints (Abildinova et al., 2024; Al-Barakat et al., 2025; Punar Özçelik et al., 2025).

The teacher-mediated interpretation is more educationally defensible than a technology-centred interpretation. BIPINIPAR's value lies not simply in its AR features but in how teachers use those features to explain, question, demonstrate, and prompt reflection. In primary classrooms, student engagement with AR can involve distinctive behaviours that differ from ordinary classroom engagement, requiring teachers to anticipate how children attend to, manipulate, and discuss AR content (Drljević et al., 2022). Motivation in AR learning is also shaped by attention, relevance, confidence, and satisfaction (Nikou, 2026), and motivational components such as scaffolding, feedback, success, and time-on-task have been linked to AR learning experiences (Bacca et al., 2018). These mechanisms imply that teacher facilitation is central to whether AR becomes meaningful learning or mere visual stimulation.

The findings also align with the specific logic of an interactive book. Research with AR storybooks, AR graphic books, and AR digital picture books suggests that book-based AR can support comprehension, motivation, attention, and retelling when the digital layer is connected to narrative or visual content (Du et al., 2024; Hung et al., 2017; Yang et al., 2026). BIPINIPAR adapts this idea to health education and PJOK: the printed page provides a stable instructional anchor, while AR visualizations make health concepts more concrete. This is important in schools where a fully digital environment may be unrealistic but printed materials remain familiar. Studies of AR e-books in Indonesia and elsewhere further suggest that contextualized book-based AR can support learning outcomes and engagement when it is culturally or pedagogically embedded (Ningsih, 2025; Tiep & Huong, 2025).

The program appraisal data provide early evidence of implementation feasibility. Material relevance, presenter skill, clarity, perceived student benefit, and overall quality were rated very highly. The comparatively lower score for ease of using the AR book in class, despite still being high, is particularly informative. Ease of use is often the fragile point in educational technology adoption. A medium may be regarded as useful and engaging, but classroom implementation requires device access, time management, teacher confidence, student grouping, stable application performance, and compatibility with lesson plans. Similar implementation issues are reported in AR studies that note technical barriers, infrastructure limitations, usability concerns, and the need for training (Amsari et al., 2025; Andayani et al., 2026; Arshad et al., 2024; Anselmo et al., 2024).

The comments requesting follow-up, more time, deeper content, and further technical access suggest that a single workshop can increase readiness but is unlikely to institutionalize practice. A stronger implementation model would include three phases: initial training, classroom pilot, and reflective follow-up. During initial training, teachers learn the conceptual and technical use of BIPINIPAR. During the classroom pilot, they apply it with pupils, document challenges, and collect student responses. During reflective follow-up, teachers and facilitators examine what worked, revise lesson strategies, and identify barriers to scale. This cyclical model is consistent with evidence that sustained professional development, instructional alignment, and support infrastructure are critical to the continued use of immersive technologies (Khlaif et al., 2025; Piedade & Batista, 2025; Salmaini et al., 2025).

The strongest scientific contribution of the present study is therefore not a claim of student learning effectiveness, but a proximal-outcome model for community-engaged educational technology implementation. Many service reports describe success through attendance and satisfaction alone. This manuscript links satisfaction to readiness, readiness to feasibility, and feasibility to a future pathway for classroom trials. The model is deliberately sequential. It recognizes that teacher readiness is the first layer, classroom implementation fidelity is the second layer, student engagement is the third layer, student learning is the fourth layer, and behavioural translation is the fifth layer. This layered view aligns with cautionary evidence that AR can be engaging without necessarily producing learning gains unless design and pedagogy are strong (Bhat et al., 2025; Bölek et al., 2021).

The implications for physical education are significant. Physical education is often treated as movement-focused, but physical education also requires teachers to teach health content that may be cognitive, behavioural, and affective. AR is not a substitute for bodily practice; it is a visual and interactive supplement that can make certain concepts easier to discuss. In physical education, AR has been found useful for motor-skill learning, learning behaviour, motivation, and acceptance when integrated with instructional tasks (Chang et al., 2020; Liang et al., 2023; Ridwan et al., 2025). BIPINIPAR should therefore be used in combination with activity. For example, an AR visualization about handwashing can be followed by practice; an AR animation about physical fitness can be linked to movement stations; an AR health scenario can lead to peer discussion or role play. This blended pedagogy preserves the embodied character of physical education.

For health education, the results encourage a move from message delivery to experiential explanation. Health lessons often involve concepts that are difficult for children to observe directly. AR health-education studies using board games and immersive scenarios indicate that digital visualization can connect health content with daily life, learner emotions, motivation, and acceptance (Jiang et al., 2026; Lin et al., 2020; Lin et al., 2021). In BIPINIPAR, the pedagogical task is to make health messages not merely more attractive but more understandable and applicable. The teacher must ask pupils what they see, why it matters, what action follows, and how the lesson connects to everyday habits. Without this reflective step, AR may entertain without producing health literacy.

The qualitative comments about AI and assessment are noteworthy. Participants did not only identify AR as interesting; many highlighted AI, rubrics, assessment, and item-generation tools. This suggests a wider professional need for resources that reduce teacher workload and improve lesson design. Future versions of the program could integrate BIPINIPAR with teacher support modules, such as sample lesson plans, formative assessment prompts, rubrics, worksheet templates, and short videos showing classroom use. Studies combining AR with intelligent tutoring, self-regulated learning, or emotionally enriched design show that immersive media may be stronger when paired with feedback, gamification, adaptive support, or reflective strategies (Alhebaishi & Stone, 2025; Alhebaishi et al., 2026; Ateş, 2025; Ateş & Polat, 2025).

A design implication concerns cognitive and emotional engagement. The ASER framework argues that AR may support retention when it combines sensory experience, emotional memory cues, interactive storytelling, and gamification (Alhebaishi & Stone, 2025), and an empirical validation later reported stronger retention and engagement in an ASER-based AR condition than in a conventional condition (Alhebaishi et al., 2026). Although BIPINIPAR was not designed explicitly as an ASER intervention, its book-based format makes storytelling and guided interaction possible. Health topics could be organized around short scenarios, for example a child choosing snacks, washing hands before eating, or responding to minor injuries. Teachers could use the AR object to trigger sensory attention and then use questions to consolidate meaning.

Another implication concerns digital equity and scalability. Reviews of AR and mobile learning repeatedly note barriers such as cost, technical difficulties, infrastructure, teacher expertise, software stability, and access to devices (Adeyele, 2025; Anselmo et al., 2024; Arshad et al., 2024). These concerns are amplified in community-engagement contexts because participating schools may have different device availability and different levels of digital confidence. The printed-book structure of BIPINIPAR is therefore a strength. It allows the lesson to proceed even when the AR layer is used selectively or in small groups. In low-resource conditions, one teacher device can be used for demonstration, while in more resourced classrooms students can explore in pairs or groups.

The results also reinforce the need to distinguish engagement from learning. Several AR studies report improved motivation, engagement, satisfaction, or attitudes, while some show mixed or non-significant effects on knowledge outcomes (Bhagat et al., 2021; Bhat et al., 2025; Bölek et al., 2021). The high appraisal scores in this study therefore should not be interpreted as proof of effectiveness for pupils. Instead, they indicate acceptance and perceived feasibility, which are necessary but insufficient conditions for impact. A classroom trial should measure whether the AR object is integrated with questioning, practice, and assessment, and whether pupils can transfer the health message into explanations or behaviours.

The movement dimension of physical education deserves further attention. Many AR interventions are screen-centred, but physical education is embodied. Movement-based learning research emphasizes that digital tools become more valuable when they are integrated into activity systems and curriculum routines (Aloizou et al., 2025). In BIPINIPAR, the most promising lesson format may be a sequence of observe, discuss, move, practise, and reflect. For instance, pupils might observe an AR visualization of germs, discuss why soap matters, practise handwashing, and then reflect on when to wash hands during the school day. This sequence would avoid reducing physical education to a screen-based lesson and would align AR with the bodily and behavioural purpose of the subject.

The study also speaks to teacher identity. Physical education teachers are not only activity managers; they are health educators, movement specialists, classroom facilitators, and assessors. The participants' interest in AI and assessment tools suggests that teachers need integrated support for planning, explaining, evaluating, and reflecting. This is consistent with research on digital integration indicating that teachers need not only technology access but also pedagogical confidence and institutional support (Abildinova et al., 2024; Al-Barakat et al., 2025). Future BIPINIPAR training could therefore include a teacher workbook, assessment rubric, and sample micro-lessons that show how to combine AR with movement tasks and formative questions.

The study also provides a local contribution. Indonesian AR education research has increasingly explored culturally situated, primary-school, vocational, and science-learning contexts (Amsari et al., 2025; Andayani et al., 2026; Herwin et al., 2023; Ningsih, 2025; Novianti et al., 2026). The present work adds elementary physical education and health education to that emerging landscape. Its contribution is practical because it responds to teacher needs in Surabaya, and conceptual because it reframes community engagement as implementation-readiness research. A local school-based innovation can become scholarly knowledge when it is connected to a theory of change, measured through appropriate outcomes, and discussed with caution about what the data can and cannot prove.

Several limitations must be acknowledged. The study used a one-group design without a control group, so changes cannot be attributed exclusively to the intervention. The outcomes were self-reported and therefore may be influenced by social desirability or immediate enthusiasm. The sample was modest and drawn from a specific community-engagement event, limiting generalisability. One baseline item used a different response scale from its paired post-training item, requiring normalization and cautious interpretation. Most importantly, the dataset does not include direct student learning, behaviour, or engagement outcomes. Therefore, the study cannot claim that BIPINIPAR improved student health literacy. The defensible claim is that the program improved teacher readiness and was perceived as highly relevant and feasible.

These limitations define the next research agenda. A second-stage study should implement BIPINIPAR in classrooms and collect pupil-level data before and after lessons. Outcomes could include health knowledge, health-behaviour intention, attention during learning, recall of AR-mediated concepts, and performance in physical education-related tasks. Classroom observation should document how teachers actually use the book, how pupils respond, and what technical or management challenges arise. A comparison group using conventional materials would strengthen causal inference. Longer follow-up would determine whether teacher readiness persists and whether the medium becomes part of regular teaching. This future design would align BIPINIPAR with the stronger experimental and quasi-experimental traditions now visible in AR learning research (Alkhabra et al., 2023; Bhagat et al., 2019; Na et al., 2025; Tarng et al., 2024).

For schools and program developers, three recommendations follow directly from the data. First, BIPINIPAR should be accompanied by a short teacher guide that includes lesson objectives, technical steps, troubleshooting notes, questions for discussion, and formative assessment examples. Second, training should include microteaching or classroom simulation so that teachers rehearse how to integrate AR with physical education activities. Third, implementation should be supported through a community of practice in which teachers share lesson adaptations, technical problems, and student responses. These recommendations move the program from product dissemination to sustainable pedagogical integration.

For researchers, the manuscript demonstrates the value of maintaining an appropriate level of claim. The topic has novelty because it combines AR, interactive books, health education, elementary physical education, and teacher capacity-building in a Surabaya community-engagement context. However, novelty alone is not enough for a strong article. The claim must be anchored in the evidence. The present data support readiness, acceptance, feasibility, and implementation lessons. They do not support direct claims about student learning gains or long-term behavioural change. This evidence-aligned framing is not a weakness; it is the basis for a credible publication pathway and a stronger future classroom effectiveness study.

The health-education strand of this work therefore should be evaluated through both cognitive and affective indicators, because AR health-education research has reported relevance for motivation, acceptance, learning outcomes, and emotional engagement (Lin et al., 2021).

6. CONCLUSIONS

BIPINIPAR, an augmented-reality interactive health-education book, appears promising as a teacher-mediated innovation for elementary physical education. Among 44 participant responses, overall readiness increased significantly after training, with the clearest gains in AR-book knowledge, AR-use skill, and confidence to teach with interactive AR media. Program appraisal was very high across relevance, presenter skill, clarity, interaction, ease of use, perceived student benefit, and overall quality. Open-ended comments confirmed that teachers valued the activity because it provided new professional knowledge, supported physical education classroom practice, introduced attractive AR and 3D media, and opened possibilities for technology-supported assessment.

The most important conclusion is not that AR automatically improves learning. Rather, the evidence indicates that teacher-mediated AR can become a credible pathway for improving elementary health education when teachers are trained, the medium is aligned with physical education content, and implementation support continues beyond a single event. BIPINIPAR should therefore be developed as part of a broader pedagogical ecosystem that includes lesson scenarios, teacher guides, assessment tools, classroom trials, and reflective follow-up. The next research phase should collect direct student data and classroom observation evidence to test whether the teacher readiness observed here translates into stronger student health literacy, engagement, and behaviour-oriented understanding.

Author information and team roles

Junaidi Budi Prihantono, S.KM., M.KM., Ph.D. served as Team Leader; Dwi Lorry Juniarisca, S.Pd., M.Ed. served as Member I; Arifah Kaharina, S.Pd., M.Kes. served as Member II; Aby Nugrah Septanto, S.Kep., Ns., M.Sc. served as Member III; and Dr. Novadri Ayubi, S.Or., M.Kes. served as Member IV. All authors are affiliated with the Program Studi Pendidikan Jasmani, Kesehatan, dan Rekreasi, Fakultas Ilmu Keolahragaan dan Kesehatan, Universitas Negeri Surabaya.

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