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The Effect of BioDigital Human Augmented Reality on Elementary Students Learning Outcomes in Hearing System Topics

Putri Fatikasari[1], Miratu Chaeroh[2], Ririn Setyowati[3]
[123] STKIP Modern Ngawi; Indonesia
Correspondence Email; skyika97@gmail.com

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Abstract

This study aimed to examine the effect of BioDigital Human-based Augmented Reality (AR) learning media on science (IPAS) learning outcomes regarding the hearing sense among fifth-grade students at MI GUPPI Ngancar. The study employed a quantitative quasi-experimental approach using a nonequivalent control group design involving 52 students, consisting of an experimental group (n = 26) and a control group (n = 26). Data were collected through a validated and reliable multiple-choice achievement test and analyzed using N-Gain and Mann–Whitney U tests. The results indicated that students who learned using BioDigital Human-based AR achieved a higher mean posttest score (M = 73.08, SD = 11.75) than those who received conventional instruction (M = 59.04, SD = 14.86). The experimental group also demonstrated a greater increase in learning outcomes (+21.15 points) compared with the control group (+8.85 points), with a moderate N-Gain score (g = 0.44) versus a low N-Gain score in the control group (g = 0.18). Furthermore, the Mann–Whitney U test revealed a statistically significant difference between the two groups (U = 172.000, Z = −3.062, p = 0.002), with a moderate effect size (r = 0.42), classified as medium, confirming that the observed effect is not merely staticsally significant but also indicating a meaningful educational impact with genuine practical relevance for classroom practice. These findings suggest that BioDigital Human-based AR learning media effectively enhances students' understanding of the hearing sense topic by facilitating interactive visualization of abstract anatomical concepts. Therefore, AR can be considered a promising instructional innovation for improving learning outcomes in primary science education, particularly for topics that are difficult to observe directly.

Keywords Augmented Reality, Hearing Sense, IPAS, Learning Outcomes, Primary School.

INTRODUCTION

Education is the right of every citizen and the foundation of human resource quality, as mandated by Article 31 of the 1945 Constitution and Law Number 20 of 2003 on the National Education System. At the primary school level, education plays a crucial role in developing students' critical and creative thinking skills as well as deep conceptual understanding (Indayana, 2025), in line with 21st-century education demands that emphasise mastery of critical thinking, creative, collaborative, and communicative skills (Vari, 2022). At the national level, this challenge is reflected in indonesia`s persistenly low science achievement the 2022 programme for international student assessment (PISA) recorded an average science score of 838 for Indonesian students, a decline of 13 points from 2018 and substantially below then OECD everage (OECD,2023) indicating that low science learning outcomes are a systemic issue rather than one confined to a single school or region. This national pattern is compounded by students` specific difficulty in comprehending human body anatomy, a topic that is widely reported as conceptually abstract becauce internal structures cannot be direcly observed and are poorly conveyed throught static textbook illustration. One indicator of the success of the learning process is student learning outcomes,which reflect the level of mastery of material and the effectiveness of the instructional strategies applied. As information and communication technology no longer serves only as a supplement, but has become a learning medium that plays a role in creating more effective and meaningful learning processes (Rahma Puteri et al., 2025)

In Islamic primary schools (Madrasah Ibtidaiyah), many students still experience difficulty understanding abstract subject matter, particularly IPAS (Natural and Social Science) material on the hearing sense. Based on preliminary interviews with the fifth-grade teacher at MI GUPPI Ngancar, technology-based learning media have not been used to the fullest extent, with learning dominated by conventional printed textbooks. Pre-study data revealed that the class average score on the hearing-sense topic was 51.06, well below the established Minimum Completeness Criterion (KKM) of 70. Out of 52 fifth-grade students, 20 students (38.46%) had not yet reached the KKM, while the remaining 32 students (61.54%) had achieved it. However, the classical completeness rate of 61.54% still falls short of the school's minimum classical completeness standard of 75% (Arikunto, 2018), indicating a gap of 13.46 percentage points between actual achievement and the required target. This gap signals that the current instructional approach, particularly the use of conventional media, requires urgent improvement to ensure all students reach the expected competencies.

The lack of variety in learning media at the primary school level shows that the use of technology in learning has not run optimally. Conventional media are still used more frequently because they are considered more practical and have long been part of classroom learning habits (Putra et al., 2023). This condition is also influenced by limited training and continuous mentoring in the development of technology-based media, so that the implementation of innovative learning media has not developed maximally (Barokah et al., 2024). Moreover, various administrative demands and time constraints in the learning process also contribute to insufficient exploration of more interactive digital media(Sari et al., 2023). Although technological facilities at the school are already available, their use in planning and implementing learning has not yet been fully and effectively integrated (Diyaurrahman et al., 2025). Furthermore, the limited availability of training and mentoring for teachers in developing AR-based media has been identified as a key barrier to the wider adoption of technology-enhanced instruction (Resti et al., 2024). Even when AR tools are accessible, teachers often lack the pedagogical knowledge required to integrate them meaningfully into their lesson plans (Dwi Indriyanti et al., 2025).

Based on the above problems, technology-based learning innovation is needed that is capable of answering the challenges of 21st-century education while being in line with the mandate of the law. The use of technology-based learning media is expected to increase student engagement and have a positive impact on learning outcomes. Therefore, this research is focused on the application of technology-based learning media as an effort to improve student learning outcomes in primary schools (Siki & Imanuel Herlimus Leba, 2025).

This problem is particularly acute for the hearing-sense material in IPAS learning. The hearing-sense topic is inherently abstract because it involves the internal structure of the ear — including the outer ear, middle ear (ossicles: malleus, incus, stapes), and inner ear (cochlea) — which students cannot directly observe or touch. Understanding the mechanism of sound transmission from the outer ear to the brain requires students to visualise complex anatomical structures and physiological processes that are invisible to the naked eye. Conventional two-dimensional textbook images are insufficient to convey this depth of understanding, so students often resort to memorising facts without genuinely comprehending how the hearing organ functions. What is needed is a medium capable of bridging the abstraction of these concepts into concrete, realistic visual experiences (Angreni et al., 2023). Interactive learning media such as Augmented Reality enables students to directly explore and manipulate learning objects, thereby optimally supporting the knowledge construction process (Alfarizi et al., 2024).

Several prior studies have investigated the use of Augmented Reality media in IPAS learning and consistently reported positive effects on student outcomes. (Imamudin, 2025) demonstrated that AR media significantly improved IPAS learning outcomes in elementary school, with the experimental group's mean score increasing by 27% and mastery rising from 62% to 85%—far exceeding the control group. (Dewi et al., 2024a) similarly found that AR media was effective in improving fifth-grade students' conceptual understanding and learning motivation, yielding an N-Gain of 0.68 and a classical mastery rate of 88% in the experimental class compared to 70% in the control class. (Pangestika & Yulianto, 2025) confirmed that a Project-Based Learning model assisted by Augmented Reality significantly improved IPAS activity and learning outcomes, producing an N-Gain of 0.72 (high category). also reported an N-Gain of 0.70 alongside a 30% increase in mean scores when AR was applied to science learning in elementary school. These studies share a common finding AR media consistently outperforms conventional media in Supporting this pattern, (Masruroh et al., 2023). found that AR-based learning media significantly enhanced students' conceptual understanding in science, with students who used AR demonstrating deeper grasp of abstract biological structures compared to those taught through conventional methods. Similarly, (Danti et al., 2023). reported that AR media in IPAS instruction at the elementary level produced a meaningful improvement in student learning outcomes, confirming its applicability across different IPAS topics and school contexts. However, they differ in scope and context (Imamudin, 2025) examined AR in general IPAS instruction, (Dewi et al., 2024) focused on fifth-grade IPAS broadly, (Pangestika & Yulianto, 2025) embedded AR within the PjBL model, and concentrated on science subjects at the general elementary level. None of these studies specifically investigated AR's effect on a single, well-defined IPAS topic such as the hearing sense, nor were they conducted at the Madrasah Ibtidaiyah level.

Despite the promising evidence summarised above, a critical gap remains: prior studies have predominantly examined AR's effect on IPAS learning in general rather than on a specific, clearly delimited topic. Research that specifically investigates the improvement of IPAS learning outcomes through AR media on the hearing-sense material is still very limited, particularly at the Madrasah Ibtidaiyah (MI) level. The hearing sense represents a uniquely challenging topic because its internal anatomical structures the ossicles, cochlea, and auditory nerve are invisible to the naked eye and cannot be adequately conveyed through static two-dimensional images in a textbook. Students at

MI therefore face a double challenge: understanding abstract biological structures and relating them to the dynamic process of sound transmission. Conventional instruction has proven insufficient for this purpose, as evidenced by the 38.46% of students at MI GUPPI Ngancar who had not yet reached the KKM prior to this study. This gap in the literature, combined with the documented need at the field level, underscores the necessity of a study that directly tests AR's effect on this specific material in this specific institutional context.

The novelty of the present study therefore lies in three dimensions. First, it examines AR's effect not on a broad IPAS curriculum but on a single, well-defined topic the hearing sense thereby providing more precise causal evidence than general IPAS studies can offer. Second, it employs BioDigital Human, a web-based interactive 3D anatomy platform, as the specific AR tool, which has not been evaluated in prior Indonesian elementary-school research. BioDigital Human enables students to rotate, zoom into, and label every component of the human ear in real time, creating a visualisation experience that is qualitatively richer than the static AR markers used in earlier studies. Third, the study is conducted at the MI level, an institutional setting that is under-represented in the AR-in-education literature yet serves a substantial proportion of Indonesian primary-school students. Together, these three dimensions produce empirical evidence that is more specific, more technologically current, and more contextually relevant than what currently exists. Based on this rationale, the hypothesis of the present study is as follows: there is a significant effect of Augmented Reality learning media on the IPAS learning outcomes for the hearing-sense topic in fifth-grade students at MI GUPPI Ngancar.

METHODS

This study employed a quantitative approach using a quasi-experimental design. A quasi-experimental design was selected because random assignment of students to groups was not feasible in the natural school setting: the two existing classes at MI GUPPI Ngancar had been formed by the institution prior to the study, making true randomization impossible without disrupting routine instruction. (John W. Creswell & J. David Creswell, 2018) explain, quasi-experimental designs are appropriate precisely in such educational contexts where intact groups are used, and full experimental control cannot be achieved, yet the researcher still introduces a deliberate treatment to one group. (Campbell, Donald T. & Stanley, 1968) further argue that the Nonequivalent Control Group Design a pretest–posttest design with a non-randomised control group provides a credible causal inference when the two groups are demonstrated to be equivalent at baseline, which was verified in the present study through a pretest equivalence test. The design is presented in Table 1.

Table 1. Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O1	X	O2
Control	O3	–	O4

Source: Sugiyono (2017)

The population consisted of all 52 fifth-grade students at MI GUPPI Ngancar, located in Ngancar Village, Pitu District, Ngawi Regency, East Java. The research was conducted from January to June 2026, encompassing instrument preparation (January–February), instrument trial and validation (February–March), data collection pretest, treatment, and posttest (March–April), and data analysis with report writing (May–June). Because the school had only two fifth-grade classes totalling 52 students, all students served as subjects, making this a census or saturated-sample study (Fraenkel, J. R., *et.al*, 2012) Class VA (n = 26) was designated as the experimental group and received AR-based instruction using BioDigital Human, while Class VB (n = 26) was designated as the control group and received conventional textbook-based instruction. The two classes were confirmed to be equivalent at baseline through a Mann-Whitney pretest equivalence test ($p = 0.068 > 0.05$).

Data were collected using a multiple-choice learning-outcome test administered as a pretest and posttest to both groups. The instrument consisted of 40 items covering two learning objectives and four cognitive levels (C1–C4) aligned with the Revised Bloom's Taxonomy. Before use, items underwent expert content validity review, followed by empirical testing using Pearson Product Moment correlation (item valid if r-count > r-table = 0.334, (Arikunto, 2018). Reliability was evaluated with Cronbach's Alpha (reliable if $\alpha > 0.60$, (Arikunto, 2018) the obtained value of 0.938 indicated very high reliability. Difficulty level and discriminating power were also analysed; items with discriminating power ≥ 0.20 (sufficient, good, or very good) were retained, yielding a final instrument of 20 items.

Data analysis followed a four-stage sequence. First, prerequisite tests Kolmogorov Smirnov normality (Field, 2018) and Levene's homogeneity—were conducted. Because the pretest data for the experimental group were non-normally distributed (sig. = $0.019 < 0.05$), all inferential analyses used non-parametric procedures. Second, the Mann–Whitney U test was applied to the posttest scores to test for between-group differences (significance criterion: $p < 0.05$). Third, learning improvement within the experimental group was quantified using the normalised gain (N-Gain) formula proposed by Hake (1998): N-Gain = (posttest score − pretest score) / (maximum score −

pretest score), with categories of high ($g > 0.70$), medium ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$). Additionally, a Wilcoxon Signed Rank Test was performed on the experimental group's paired pretest–posttest scores to confirm the significance of within-group improvement. Fourth, to assess the practical magnitude of the treatment effect beyond mere statistical significance, Cohen's r effect size was calculated from the Mann–Whitney Z-value using the formula $r = Z / \sqrt{N}$ (Cohen, 1988; Field, 2018), with benchmarks of small ($r = 0.10$), medium ($r = 0.30$), and large ($r = 0.50$).

FINDINGS AND DISCUSSION

Findings

Instrument Validity and Reliability

Of the 40 test items administered, 31 items were declared valid (r-count > r-table = 0.334), while 9 items were invalid and excluded. The Cronbach's Alpha reliability value was 0.938 (> 0.70), indicating a very high level of reliability. Based on difficulty-level analysis, most items were in the easy and medium categories. Discriminating-power analysis showed that most items fell into the very good, good, and sufficient categories. Accordingly, 20 items were selected as the final research instrument.

Descriptive Statistics by Group

Table 2 presents the descriptive statistics separated by group (experimental vs. control) and by test phase (pretest vs. posttest), enabling a direct comparison of learning outcomes across conditions.

Table 2. **Descriptive Statistics of Pretest and Posttest by Group**

Statistics	Exp. Pretest	Exp. Posttest	Ctrl. Pretest	Ctrl. Posttest
N	26	26	26	26
Mean	51.92	73.08	50.19	59.04
Median	50.00	75.00	50.00	60.00
Mode	55	75	40	60
Std. Deviation	16.42	11.75	18.84	14.86
Minimum	20	50	20	30
Maximum	80	95	90	90
Gain Score (Mean)	**+21.15**	–	**+8.85**	–

Source: Processed SPSS Output. Note: Gain Score = Mean Posttest – Mean Pretest.

Before treatment, both groups showed comparable initial ability: the experimental group had a mean pretest score of 51.92 (SD = 16.42) and the control group 50.19 (SD = 18.84). After treatment, the experimental group's mean posttest score rose to 73.08 (SD = 11.75), representing a gain of +21.15 points, whereas the control group's mean posttest score increased only modestly to 59.04 (SD = 14.86), a gain of +8.85 points. The standard deviation in the experimental group also decreased from 16.42 to 11.75, indicating that AR-based instruction produced more uniform achievement — students who had previously scored at lower levels showed greater improvement under AR instruction than under conventional methods.

N-Gain Analysis

To determine the category of learning improvement, the Normalised Gain (N-Gain) was calculated for each group using the formula: N-Gain = (Posttest – Pretest) / (100 – Pretest). Categories follow Hake (1999): High (≥ 0.70), Medium (0.30–0.69), Low (< 0.30).

Table 3. N-Gain Analysis of Learning Outcomes

Group	Mean Pretest	Mean Posttest	N-Gain (Category)
Experimental (AR)	51.92	73.08	0.44 (Medium)
Control (Conventional)	50.19	59.04	0.18 (Low)

Source: Calculated from group mean scores.

The experimental group achieved an N-Gain of 0.44, classified as medium, while the control group obtained an N-Gain of 0.18, classified as low. This difference confirms that AR-based learning using BioDigital Human produced meaningfully greater improvement in student learning outcomes than conventional instruction. The medium-category N-Gain in the experimental group indicates that AR media effectively enhanced students' understanding of the hearing-sense material beyond what baseline ability alone would predict.

Bar Chart: Mean Score Comparison

Figure 1 below present the mean pretest and posttest scores of both groups as bar chart, with shaded bands indicating the low (<60), medium (60-74), and high (>75) score categories, making the differential gain and category shift immediately visible. The corresponding numerical values are reported in table 4. Both group began in the low category before treatment. After treatment, the experimental group moved into the medium category (mean =73.08). whereas the control group`s mean posttest score (59,04) remainded within the low category, illustrating that AR-based instruction was sufficient to shift the experimental group`s everage performance up one category band while conventional instruction was not.

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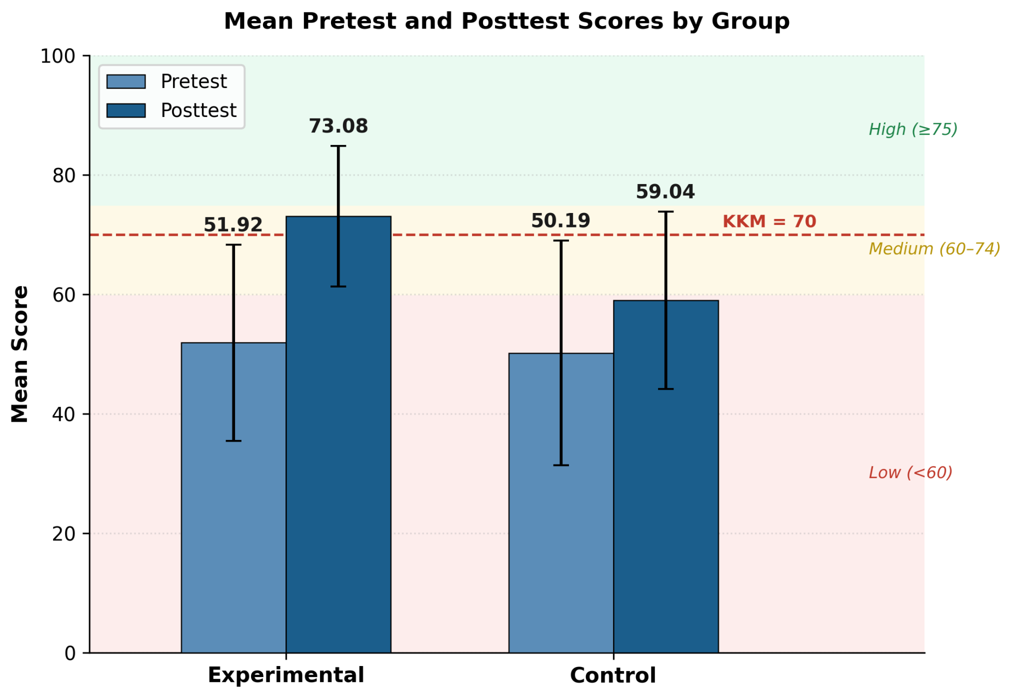

Table 4. Mean Pretest and Posttest Scores by Group, with score categoryle, 3 Baris, 5 Kolom

Group	Mean Pretest	Pretest category	Mean Posttest	Posttest category
Experimental	51.92	Low	73.08 (+21.15)	Medium
Control	50.19	Low	59.04 (+8.85)	Low

Note: Values in parentheses indicate mean gain score. Score categories follow the bands low (<60), medium (60-74), and High (>75), as also depicted in figure 1.

Prerequisite Tests: Normality and Homogeneity

Table 4 consolidates the normality and homogeneity test results. The pretest data for the experimental group did not meet the normality assumption (sig. = 0.019 < 0.05), justifying the use of a non-parametric test for hypothesis testing. All other groups met the normality assumption. Both pretest and posttest data across groups were homogeneous.

Table 4. Normality and Homogeneity Test Results

Test	Group	Statistic	Sig.	Decision
Normality (K-S)	Exp. Pretest	0.187	0.019	Not Normal
Normality (K-S)	Ctrl. Pretest	0.158	0.094	Normal
Normality (K-S)	Exp. Posttest	0.145	0.166	Normal
Normality (K-S)	Ctrl. Posttest	0.144	0.179	Normal
Homogeneity (Levene)	Pretest	0.596	0.444	Homogeneous
Homogeneity (Levene)	Posttest	2.530	0.118	Homogeneous

Source: SPSS 25 for Windows.

Hypothesis Testing: Mann-Whitney U

Table 5 presents the complete Mann-Whitney test statistics, including Mean Rank values and the computed effect size.

Table 5. Mann-Whitney Hypothesis Test Results with Effect Size

Statistics	Pretest	Posttest
Mann-Whitney U	238.500	172.000
Wilcoxon W	589.500	523.000
Z	-1.828	-3.062
Mean Rank (Exp. / Ctrl.)	22.67 / 30.33	32.88 / 20.12
Asymp. Sig. (2-tailed)	0.068	0.002
Effect Size ($r = Z/\sqrt{N}$)	0.25 (Small)	0.42 (Medium)

Source: SPSS 25 for Windows. Effect size $r = Z / \sqrt{N}$ (Cohen, 1992): small ≥ 0.10, medium ≥ 0.30, large ≥ 0.50.

For the pretest, the Mann-Whitney U = 238.500 with Z = -1.828 and sig. = 0.068 (> 0.05), confirming no significant difference in initial ability between groups (H_0 accepted). The Mean Rank for the experimental group (22.67) was slightly lower than for the control group (30.33), indicating comparable or marginally lower starting points for the experimental class. For the posttest, U = 172.000, Z = -3.062, and sig. = 0.002 (< 0.05), so H_0 is rejected and H_2 is accepted: there is a statistically significant difference in learning outcomes after treatment. The Mean Rank reversal — experimental group 32.88 vs. control group 20.12 — confirms that the experimental group substantially outperformed the control group after AR-based instruction. The effect size r = 0.42 is classified as medium, indicating that AR media produced a practically meaningful, not merely statistically significant, improvement in learning outcomes.

Discussion

The results confirm that AR-based learning through BioDigital Human significantly improves IPAS learning outcomes on the hearing-sense topic in fifth-grade MI students. Three theoretical frameworks help explain this finding. First, from a constructivist perspective (Vygotsky, 1978):(Piaget, 1970), AR supports active knowledge construction by positioning students as explorers of three-dimensional anatomical structures rather than passive recipients of textbook explanations. When students rotated and labelled the ossicles and cochlea in BioDigital Human, they were engaging in the kind of hands-on cognitive manipulation that constructivism identifies as essential to deep learning. The students' increased questioning and discussion behaviour observed during AR lessons is consistent with Vygotsky's Zone of Proximal Development: the interactive medium scaffolded learners just beyond their current understanding, prompting productive cognitive engagement.

Beyond this constructivist explanation , three specific principles of mayer`s cognitive theory of multimedia learning map directly onto features of BioDigital human `itself. The spatial contiguity principle, which states that learning is deeper when corresponding words and images are placed near each other rather than sparated on the page, is relised in BioDigital Human through its real-time labelling function when a student rotates or zooms into the ear model, the name of each structure the ossicle, the coclea, the auditory nerve appears directly attached to that structure on the 3D model itself, rather than in a separate legend or caption as in a textbox diagram. Eliminating the split-attention effect that occurs when student must visually search back and forth between an image and its separate label list. The coherens principle, which holds that learning improves when extraneous material is exclude, is reflected in how the teacher-directed BioDigital Human projection in this study isolated the ear and its associated hearing-sense sructures rather than displaying the full anatomical model with unrelated organ system visible, keeping students visual attention on the single structure being taught rather than diluting it across extraneous anatomical detail.

Finally, the modality principle, which predicts that learning is deeper when explanatory information is presented as spoken narration alongside images rather than as on creen text competing with the same visual channel as the image. Corresponds to BioDigital Humans combination of the 3D visual model with the teachers concurrent spoken explanation of the sound transmission process the visual channel carried the rotating, zoomable anatomical structure while the auditory channel carried the verbal description of how sound waves travel throught the ossicles to the cochlea, distributing the infoemation load across both processing channels instead of overloading the visual channel alone, as a statistic, unlabelled textbook diagram read silently would do. Togerther, these three principles show that it is BioDigital Humans specific multimedia design features and not merely its three-dimensionality as such that ware positioned to reduce extraneous cognitive load and support deeper processing of the hearing sense material than the static,text heavy textbook page used in the control condition.

Second, (Mayer, 2021) provides a precise explanation for why AR outperformed textbooks in this context. The hearing-sense topic requires students to simultaneously understand spatial structure (where each part of the ear is located) and dynamic process (how sound waves are converted into neural signals). Mayer's dual-channel assumption holds that visual and verbal information are processed in separate channels; when the two channels are loaded coherently as in BioDigital Human's synchronised 3D model and explanatory audio-text learning is deeper than when only one channel is used. The textbook's static 2D images, by contrast, impose a higher cognitive load on students who must mentally reconstruct three-dimensional anatomical relationships from flat representations, leaving fewer cognitive resources for genuine conceptual understanding. This advantage of AR over static media in anatomical learning has also been confirmed in a systematic review by (Bölek et al., 2021), who found that AR consistently reduced cognitive load while increasing student motivation and engagement across multiple anatomy education contexts a finding that directly parallels the present study's results with the hearing-sense topic.

Third, (Paivio, 1986) supports the observed advantage of AR: information encoded both visually (the 3D model) and verbally (labels and explanations) is more likely to be retained and retrieved than information encoded in only one modality. This is consistent with the posttest results: the experimental group's higher mean score and lower standard deviation indicate both greater average achievement and more consistent retention across students.

Comparing the present findings with prior studies reveals both convergence and distinctive contributions. (Imamudin, 2025) reported a 27% mean-score increase with AR in general IPAS instruction; the present study found a 40.6% increase ((73.08 - 51.92) / 51.92 × 100) in the experimental group, suggesting that targeting a single well-defined topic with a richer AR platform (BioDigital Human) amplifies the effect observed in general IPAS studies. (Dewi et al., 2024) achieved an N-Gain of 0.68 (medium-high) using a static AR marker application for fifth-grade IPAS; the present study's N-Gain of 0.44, while medium, is contextually strong given that BioDigital Human was deployed as a teacher-directed projection tool rather than as an individually operated device — a mode that reduced per-student interaction time compared to Dewi et al.'s setup. (Pangestika & Yulianto, 2025) embedded AR within the PjBL framework and obtained N-Gain = 0.72 (high); the higher gain likely reflects the additional motivational and collaborative scaffolding that PjBL provides, suggesting that combining AR with project-based pedagogies could further enhance outcomes in future research. Crucially, none of the prior studies examined the hearing-sense topic specifically, conducted research at the MI level, or employed BioDigital Human as the AR platform three dimensions that constitute the novelty of the present work. The present findings also align with (Alfarizi et al., 2024), whose development study of AR media for IPA demonstrated that AR-based tools are not only technically valid but also practically effective in raising student learning outcomes — reinforcing the conclusion that AR media is a viable, evidence-based instructional choice for elementary science education in the Indonesian context.

The practical significance of the findings is equally noteworthy. Prior to this study, 38.46% of students (20 out of 52) had not reached the KKM. After AR-based instruction in the experimental class, the group's mean posttest score of 73.08 exceeded the KKM of 70, and the reduction in standard deviation (from 16.42 to 11.75) indicates that lower-achieving students benefited disproportionately from the visualisation support that AR provided. This suggests that AR media not only raises average performance but also reduces learning inequality within the classroom — an important equity consideration for MI schools that often serve diverse student populations with varying levels of prior knowledge and learning support at home.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the use of Augmented Reality-based learning media through the BioDigital Human website is able to create a more interactive, attractive, and meaningful learning process. This media helps students understand the hearing-sense material that is abstract in nature to become more concrete through three-dimensional visualisation of the ear organ, so that students are more active, enthusiastic, and involved during the learning process.

The results of hypothesis testing using the Mann-Whitney test showed a posttest significance value (Sig. 2-tailed) of $0.002 < 0.05$, so H_0 was rejected and H_a was accepted. It is therefore concluded that there is a significant effect of Augmented Reality learning media on IPAS learning outcomes for the hearing-sense topic in fifth-grade students at MI GUPPI Ngancar. These results confirm that AR-based learning media constitute an innovative and effective solution for improving the quality of primary education, particularly for abstract IPAS topics.

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