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Research Article

Development of interactive hologram-based learning media for physical education sports and health subjects in elementary school

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ABSTRACT
Background: Physical education sports and health material sports games still use conventional methods by relying on books and other tools. Technology-based interactive media has yet to be applied to interactive learning. Objective: This study aims to produce hologram-based interactive learning media that effectively increase student knowledge. Methods: This study used the Research and Development (RnD) method. This study used a sample of 5th-grade students from State Elementary School 1 Tinggarwangi 26 students, State Elementary School 3 Jambu 16 students, and State Elementary School 1 Banteran 20 students. Research instruments for media use validation questionnaires and student and teacher assessments. Cognitive aspect research instruments use questions that previously passed the validity stage. The data analysis technique uses quantitative description, including Normalits, Homogeneity, and T-tests. Result: Based on the assessment results from media experts, material experts, linguists, teachers, and students, the earning media produced a feasible category for the learning process. The effectiveness test results show that interactive learning media effectively increases students' knowledge. Conclusion: Interactive learning media for big and small ball games is very feasible for use as learning media for elementary/equivalent students.

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Development; interactive learning media; cognitive aspects; sports games.

Introduction

Education aims to develop an individual's personality by evaluating each stage of education to enhance positive potential and overcome negative potential. Humans have three essential components: heart, mind, and physique. Thus, character building through education must pay attention to and involve these three aspects in self-management (Arfani, 2016). However, in the digital era, conventional education methods often fail to accommodate students' learning preferences, particularly in physical education, sports, and health, where practical engagement is critical.

According to Law No. 20/2003 on the National Education System, education is a conscious and planned effort to create a learning environment that enables learners to develop their potential actively. This includes spiritual strength, religion, self-control, personality, intelligence, noble character, and skills needed for oneself, society, nation, and state. Physical Education, Sports, and Health can play an important role in developing motor skills, knowledge, and attitudes and shaping students' mental, emotional, spiritual, and social character. Despite this importance, many educators struggle to integrate effective teaching methods that enhance students' engagement and comprehension, particularly in the digital age where traditional teaching approaches may not be as effective.

Physical education is learning that emphasizes movement and physical activity. Practice takes precedence over theory, focusing on movement experiences to achieve learning objectives (Mulyanto, 2014). Activities include games, sports, recreation, and adventure. According to Muhajir & Raushanfikri

(2022), the scope of PJOK subjects includes basic movement, game sports, martial arts, athletics, physical fitness, gymnastics, rhythmic movement, water activities, and health. However, limited access to interactive learning media often hampers students' ability to grasp complex concepts and develop their motor skills effectively. This highlights the urgent need to explore innovative teaching strategies that enhance learning outcomes.

Learning media is a communication tool for teachers and students to convey material. The types vary from simple to sophisticated (Maulidia & Ridwan, 2021). There are those made by teachers themselves or mass-produced, as well as natural and specialized media designed for learning. Safitri & Djuniadi (2021) argue that children of the digital generation prefer images and animations to teachers' oral explanations. They are familiar with tablets and smartphones and prefer learning through digital devices. One alternative is holography technology, which allows the creation of three-dimensional objects that can be viewed from various angles.

Holography is a three-dimensional image result using image recording techniques in interference events recorded through a two-dimensional medium called a hologram (Istiana et al., 2021). Holograms can deliver information in a more interactive and immersive 3D arrangement, allowing students to understand complex and abstract concepts more easily. In addition, holograms can also increase students' motivation and interest in learning due to more realistic 3D objects. Another benefit is the ability of holograms to improve students' visualization and spatial skills and support them in solving more complex problems. Research from Nugroho & Purwanto (2021) shows that using hologram-based interactive media in teaching and learning activities can make it easier and make students enthusiastic about learning. Research conducted by Muhson (2010) shows that using Information Technology (IT) in learning media is a mandatory demand.

Despite these benefits, research on the application of hologram technology in elementary school learning remains limited, presenting a gap in the literature. Most previous studies have focused on higher education levels, leaving a lack of evidence regarding its effectiveness for younger learners. Additionally, few studies have explored the integration of hologram media specifically for physical education and health subjects, creating an opportunity to address this gap.

This research was conducted by developing hologram interactive learning media through Adobe Premiere Pro and Adobe After Effects software to improve students' cognitive aspects. Adobe Premiere Pro and Adobe After Effects are prevalent software in the creative industry, especially in video editing and motion graphics. Adobe Premiere Pro has advanced video editing features, such as multi-camera editing, color grading, and audio editing. Premiere Pro can be integrated with other software to facilitate the work process and complete projects quickly. In addition, Premiere Pro supports various file formats. After Effects offers a variety of advanced motion graphics features. By using Adobe Premiere Pro and Adobe After Effects, users can create more complex and professional video projects and improve their creative abilities in video editing and motion graphics.

This study aims to strengthen previous research on using hologram technology in learning by providing new insights into its application at the elementary school level. By addressing the existing research gap, this study contributes to the field of education by demonstrating how hologram-based learning media can enhance students' engagement and understanding in physical education. Furthermore, the findings offer practical implications for teachers, enabling them to incorporate digital innovations to optimize the learning experience for digital-native students.

Method

Research Design

This research has received research ethics approval from the Research Ethics Commission of the Faculty of Health Sciences, Jenderal Soedirman University, with Number 1399/EC/KEPK/III/2024. The research method used by researchers in the research to be carried out uses the research and

development method or Research and Development (R&D). Research and development (R&D) in education is used to develop and validate products used in learning (Hanafi, 2017). The research flow is shown in Figure 1.

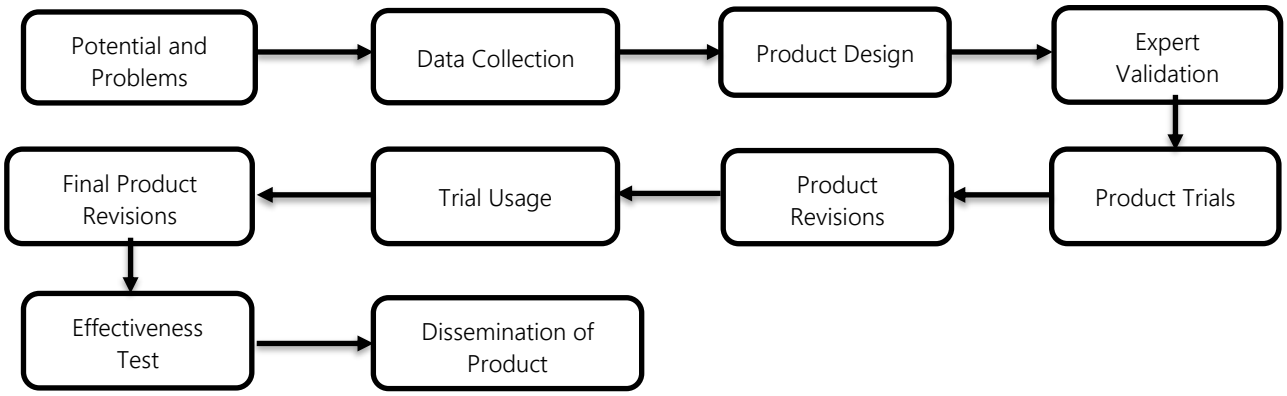


Figure 1. RnD Research Flow

Testing the effectiveness of the developed product was conducted structured, with a pre-test and post-test to indicate increased student understanding before and after using the learning media developed by the researcher. The quasi-experiment method was used with an unequal control group design method (Table 1).

Table 1. Nonequivalent Control Group Design

Pretest	Treatment	Posttest
O1	X	O2
O3	(-)	O4

Description :

O1 : Pretest of Group using Hologram-based Interactive Learning Media
O2 : Posttest of Group using Hologram-based Interactive Learning Media
O3 : Pretest of Group using Media Other than Hologram Interactive Learning
O4 : Posttest of Group using Media Other than Hologram Interactive Learning
X : Treatment using hologram-based interactive learning media
(-) : Treatment using another learning model

The division of treatment groups uses the ordinal pairing technique. This technique ranks the pre-test results and sorts them using the ABBA formula to create two groups. The determination of which group will use interactive learning media is drawn because each group deserves the same opportunity.

Participants

The research sample consisted of students and teachers from 3 different schools, with details in Table 2.

Table 2. Research Sample

No.	The Research and Development Phase	Schools	Number of Samples
1	Small-scale Test	State Elementary School 1 Tinggarwangi.	26 students
2	Product Use Trial and Effectiveness Test	State Elementary School 3 Jambu and State Elementary School 1 Banteran	36 students and 2 PE Teachers
	Total		62 students and 2 PE Teachers

Research Instruments

Research instruments data were collected using a quantitative descriptive method, using a questionnaire with a Likert scale from 1 to 5. Data sources include evaluations from media experts, material experts, linguists, students, and teachers. The following is a description of the Likert scale range (Sugiyono, 2022) (Table 3).

Table 3. Likert Scale Range

Score/Point	Category
5	SB (Excellent)
4	B (Good)
3	C (Enough)
2	K (Poor)
1	SK (Very Poor)

Based on the Likert scale above, it is then converted using the overall percentage using the following formula:

$$P = \frac{f}{n} \times 100$$

Description:

P : Percentage (%)

f : Total score/points earned

n : Total number of scores/points

Table 4. Assessment Criteria

Percentage	Criteria
≥ 80%	Learning media is very feasible to use
60% < X ≤ 80%	Learning media is suitable for use
40% < X ≤ 60%	Learning media is sufficient for use
20% < X ≤ 40%	Learning media is not suitable for use
X ≤ 20%	Learning media is not very suitable for use

The product development progress of this study was carried out gradually through a series of structured stages in learning media development. The media was developed, tested, and assessed by teachers, students, and three primary validations (media, material, and language experts). The hope is that the learning media produced can be used to teach elementary school students physical education. This research uses holography media to create interactive learning media for game material in reflection holograms. Reflection holograms were chosen because they can be used through smartphones using block-shaped reflectors made of glass, mica, or acrylic placed diagonally inside.

Data Analysis

Data analysis to determine the level of product effectiveness using the SPSS application with Normality and Homogeneity tests with the provision of sig>0.05. Paired Sample Test is used to determine whether there is a significant change between samples. If the significance value (2-tailed) <0.05, it indicates a significant difference.

Results and Discussion

Potential and Problems

Observations and interviews with Physical Education, Sports and Health (PJOK) teachers at State Elementary School 3 Jambu, Wangon District, show that learning game sports material is still conventional by relying on books and other tools. During the Children's Teaching Campus activities, it

was shown that students were quickly bored without interactive learning media. Only 15% of students passed the PJOK subject test. Technology is only used in rhythmic gymnastics material through learning videos. Game sports material was chosen because the learning is more practical. There are two types of materials: big balls (such as basketball, volleyball, and football) and small balls (such as badminton, table tennis, and taste). Basketball, volleyball, football, and badminton were chosen because the equipment is readily available and often played at school. Therefore, researchers chose to develop these four materials through interactive learning media.

Problem identification in the research consisted of field studies and literature studies. The field study involved direct observation at State Elementary School 3 Jambu, while the literature study was conducted by reading references from journals and books (Table 5).

Table 5. Identification of Problems

No.	Type of Study	Activity	Result
1.	Field	Interview	Theoretical learning media in the classroom using books.
		Observation	a. The learning is conventional b. Teachers have not implemented technology-based learning media.
2.	Literature	Learning Materials	a. Basic techniques of Basketball b. Basic techniques of Volleyball c. Basic techniques of Badminton d. Basic techniques of Football
		Hologram Manufacturing	a. *Adobe Premiere Pro* b. *Adobe After Effects*

The field study results show that schools use conventional learning methods without using technology, relying on textbooks. However, the literature study shows game sports material covering several basic sports techniques. Interactive learning media, such as holograms, is created using Adobe Premiere Pro and Adobe After Effects tools to improve learning. The video will be projected into a three-dimensional hologram with the help of a reflector, and access will be provided through a mini book.

Information Collection

Information was collected about the sports games taught to elementary school students, including basketball, volleyball, badminton, and football, and the various basic techniques in each game. The result is Table 6.

Based on the Table 6, learning materials for sports games include basic techniques from several sports. For basketball, basic techniques include dribbling, catching the ball, and passing. For volleyball, basic techniques involve lower serving, upper serving, lower passing, and upper passing. For badminton, basic techniques include footwork, forehand shots, and backhand shots. As for football, basic techniques involve kicking the ball, dribbling, stopping the ball, and heading the ball. This information is used as a reference when making materials in interactive learning media.

Table 6. Information Collection

No.	Information Type	Discussion	Result
1.	Learning materials for elementary	Basic techniques of Basketball	a. Dribbling (static and dynamic) b. Catching the ball c. Passing (Chest pass, Overhead pass, Bounce pass, Javeline pass)

Continued Table 6. Information Collection

	school sport games	Basic techniques of Volleyball	a. *Servis* b. *Passing*
		Basic techniques of Badminton	a. *Footwork* b. *Serve* c. *Handle* d. *Stroke*
		Basic techniques of Football	a. Passing b. Dribbling c. Stopping the ball d. Head the ball
2.	Academic	Learning Outcomes	Out of 20 students, 17 students scored below the minimum completion criteria.

Product Manufacturing

Making interactive learning media products for game sports includes making illustrations, taking videos of materials to be edited, editing processes using Adobe Premiere Pro and Adobe After Effects, making guidebooks, accessing QR codes, and asking questions.

a. Illustration Making

The following illustrates the interactive learning media that has been made.

1) Illustration of Basketball materials

Figure 2. Illustration of Basketball Learning

2) Illustration of Volleyball materials

Figure 3. Volleyball Learning Illustration

3) Illustration of Badminton materials

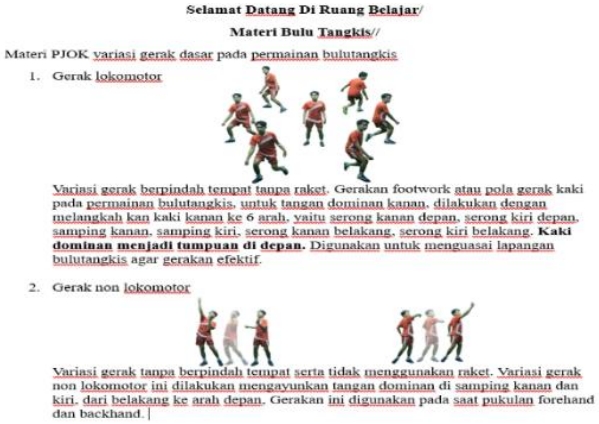


Figure 4. Illustration of Badminton Learning

4) Illustration of Football materials

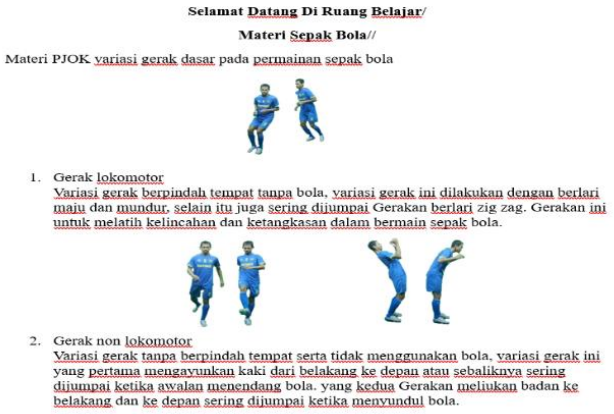


Figure 5. Illustration of Football Learning

b. Media Creation

Here are the steps for making hologram media

1) Video production

Figure 6. Video Making

2) Holographic reflector manufacturing

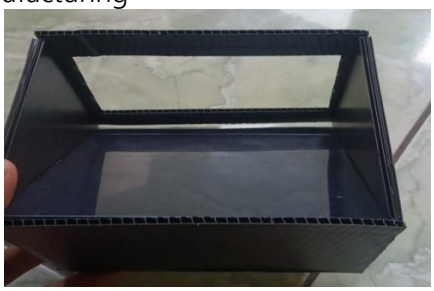


Figure 7. Hologram Reflector Manufacturing

c. Formulation of Question Items

The process of preparing 40 questions involves several stages. Each question is adjusted to the framework that has been designed and must pass the validity, difficulty level, differentiating power, and reliability tests. The process began with developing the lattice into question items, which were then tested on students of State Elementary School 2 Tinggarwangi and State Elementary School Pagentan with the participation of 39 students. The following are the tests carried out in the preparation of the questions.

1) Validity Test

The validity test serves to assess the consistency of each test item. An instrument of test items is considered valid if the calculated r value is greater than the r value in the table. The validity test results are shown in Table 7.

Table 7. Validity Test Resutl

No	Description	Questions Number	Number of Questions
1	Valid	,2,3,5,6,7,8,9,12,13,15,16,18,19,20,21,22,23,24,26,27,30,31,32,33,34, 35,37,38,39	29 Questions
2	Invalid	1,4,10,11,14,17,25,28,29,36,40	11 Questions

From the results of the validity test of 40 questions, 11 were invalid, with an r value ≤ 0.31. The invalid questions were examined, considering the difficulty level and differentiating power before being removed.

2) Test of Question Difficulty Level

Item difficulty (p) is between 0.00 and 1.00, indicating how many test takers answered the item correctly. When the value is close to 0.00, the item is considered difficult, while if it is close to 1.00, it is considered easy. The formula for calculating item difficulty is the number of participants who answered correctly divided by the total number of participants. The item difficulty level is divided into three categories: p-value> 0.7 "Easy," Value 0.3 ≤ p ≥ 0.7 "Medium," and Value p < 0.3 "Difficult." Below are the results of the item difficulty test:

Table 8. Question Difficulty Level

No.	Category	Question Number	Number of Questions
1	Easy	1,3,4,11,19,22,30	7 questions
2	Medium	5,6,7,8,9,10,12,13,14,16,17,18,21,23,24,25,26,27,31,32,33,34,35,36,3 7,39,40	27 questions
3	Difficult	2,15,20,28,29,38	6 questions

The difficulty level of the questions from a total of 40 items that have been prepared, with each category having a percentage of 17.5% easy questions, 67.5% medium questions, and 15% difficult questions. Based on the Table 8, the question category is moderate.

3) Test of Differentiation Power

Differentiation power assesses the difference in items between low and high-ability test takers. The upper and lower groups were determined to account for 25% of the data. Table 9 is the result of the differentiating power test.

Table 9. Differentiation Power

No.	Category	Question Number	Number of Questions
1	Very Good	2,3,5,6,7,9,13,15,16,19,22,23,26,31,32,33,34,35,37,38,39	21 questions
2	Good	8,14,20,21,24,27	6 questions
3	Enough	12,18,29,30,40	5 questions
4	Eliminate	1,4,10,11,17,25,28,36	8 questions

Based on Table 9, 40 items are prepared. A total of 21 questions were categorized as "very good," 6 questions were in the "good" category, five questions were in the "fair" category, and eight questions were considered "irrelevant." A total of 10 questions were discarded due to consideration of the results of the question difficulty test and the power difference test.

4) Reliability Test

Test reliability can determine whether the test is reliable according to predetermined standards. Table 10 is the result of the reliability test for the question.

Table 10. Reliability Test Result

Cronbach's Alpha	*N of Items*	Description
.763	29	Hingh

The research instrument is said to be reliable if the Cronbach's Alpha value is> 0.60 (Ghozali, 2016). Therefore, the reliability test of 29 instruments obtained a Cronbach's Alpha value of 0.763> 0.6 to declare it consistent or reliable.

d. Guidebook Making

1) Guidebook cover

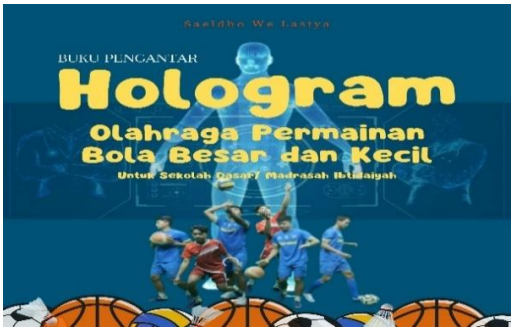


Figure 8. Guidebook Cover

2) Material Title

Figure 9. Material Title

3) Learning Evaluation

Figure 10. Learning Evaluation

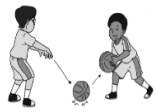
Design Validation

The design validation involved media experts, material experts, and linguists whose validation process is shown in Table 11. Make improvements to the product after getting suggestions and input from media experts, material experts (basketball, volleyball, badminton, football), and linguists. The expert's suggestions made improvements. Table 12 is the improvement recommendation for interactive learning media.

Table 11. Design Validation

No.	Experts	Validator Name	Percentage	Comments and Suggestions
1	Media Expert	Muhammad Syaiful A, S.T., M.T.	96,3% (Highly Feasible)	Use a sturdier quality material that is black in color.
2	Basketball Material Expert	Ajeng Dian Purnamasari, S.Pd., M.Or.	98,94% (Highly Feasible)	Plus instructions on how to do the questions.
3	Volleyball Material Expert	Kusnandar, S.Pd., M.Kes.	80% (Highly Feasible)	Alright, continue for research.
4	Badminton Material Expert	Indra Jati Kusuma, S.Pd., M.Or.	81,05% (Highly Feasible)	Please correct the type of punch.
5	Football Material Expert	Panuwun Joko Nurcahyo, S.Pd., M.Pd.	100% (Highly Feasible)	Please do it according to the learning steps so that students can understand better.
6	Language Expert	Lalita Melasariati, S.Pd., M.Pd.	100% (Highly Feasible)	

Table 12. Design Revisions

No.	Assessor	Revision Results	
		Before	After
1	Media Expert		
2	Material Expert	 6. Berdasarkan gambar di atas, dua anak tersebut sedang melakukan … a. *Bounce pass* c. *Overhead pass* b. *Chest pass* d. *Javeline pass*	 6. Berdasarkan gambar di atas, dua anak tersebut sedang melakukan … a. *Bounce pass* c. *Overhead pass* b. *Chest pass* d. *Javeline pass*
3	Language Expert	Writing: • *"Servis"* • *"Manipulative"* • *"Diatas"* • *"Kedepan"* • *"Reflektor"*	Writing: • *"Servis"* • *"Manipulatif"* • *"Di Atas"* • *"Ke depan"* • *"Reflektor"*

Product Trial

After making improvements, the product was tested on grade 5 students of State Elementary School 1 Tinggarwangi. A total of 26 respondents were initially allowed to try the learning media before being given an assessment form by the researcher. The following is the evaluation of the product trial. Based on Table 13, the product trial results of 26 respondents who gave an assessment, 91.3%, were calculated to be very feasible by the criteria.

Table 13. Small Scale Test

No.	Type	Description
1	Number of Respondents	26 Respondents
2	Percentage	91,3%
3	Criteria	Highly Feasible

Product Revision

Product revision is a step taken based on the results of product trials involving 26 respondents, with the revisions made as follows:

Table 14. Product Revision

No.	Indicator	Forms of Improvement
1	Component	Writing
2	Initial Condition	Reflected upside down
3	Follow-up	Re-edit according to reflection

Based on the data in Table 14, it can be concluded that the interactive learning media found editing errors related to inverted text on the hologram video content. The researcher's follow-up is to revise the edits by flipping the text horizontally so that when it is reflected, it is readable.

Trial Usage

The usage trial was conducted during the revision stage after product testing was completed. The number of respondents was expanded and carried out at Jambu 3 State Elementary School and Banteran 1 State Elementary School. Usage testing was carried out by adding and changing the target schools.

Table 15. Large Scale Test

No.	Type	Trial Usage	
1	Data	Student Assessment	Teacher Assessment
2	Number of Respondents	36 Respondents	2 Respondents
3	Percentage	92.028 %	89,5 %
4	Criteria	Highly Feasible	Highly Feasible

Based on the results of the usage trial in Table 15, 36 respondents from students and two respondents from teachers obtained a percentage of 92.028% and 89.5%, which showed very feasible criteria.

Product Revision

Based on the results of the usage trial, no obstacles were found, so this product revision was continued to the next stage, namely the effectiveness test.

Effectiveness Test

The effectiveness test aims to evaluate the use of interactive learning media by elementary school students. The effectiveness test was conducted using two schools, Jambu 3 State Elementary School and Banteran 1 State Elementary School, with 36 students from both schools.

Pre-tests were analyzed in each school and then sorted using the ordinal pairing method to divide control and treatment groups by drawing lots. After that, the effectiveness test was conducted for four meetings, followed by post-test data collection.

Processing data before and after the test by conducting several stages of testing such as 1) Descriptive Analysis, 2) Normality Test, 3) Homogeneity Test, and 4) Paired Sample T Test. The group that does not use interactive learning media will get code "A," and the group that uses interactive learning media will get code "B."

Table 16. Group Distribution of State Elementary School Banteran 1

No.	Initial	Group A	No.	Initial	Group B
1	GAR	73.33	2	AUHJ	70
4	KRA	60	3	MRBA	66.67
5	NPH	56.67	6	AAS	53.33
8	FDP	53.33	7	DBF	53.33
9	SH	50	10	AA	46.67
12	RT	43.33	11	HST	46.67
13	NAE	40	14	FMF	36.67
16	FA	23.33	15	LSZ	30
Total		399.99	Total		403.34

Table 17. Group Distribution of State Elementary School 3 Jambu

No.	Initial	Group A	No.	Initial	Group B
1	FSPB	73.33	2	DMR	63.33
4	QNA	53.33	3	MAP	56.67
5	AAK	50	6	NMW	46.67
8	RA	43.33	7	DMZ	46.67
9	HDR	43.33	10	TSNC	36.67
12	SO	36.67	11	AF	36.67
13	KGN	36.67	14	FN	36.67
16	FDA	30	15	AN	30
17	RM	26.67	18	SMAF	26.67
20	IM	20	19	NTR	23.33
Total		413.33	Total		403.35

Descriptive Analysis

Descriptive analysis was used to evaluate the data obtained from the previous tests. This analysis includes determining the minimum, maximum, average, and data distribution values. The following are the results of descriptive analysis after all pre-test and post-test data has been collected:

Table 18. Descriptive Analysis Result

No.	Data	N	Minimum	Maximum	Mean	Std. Deviation
1	*Pretest A*	18	20	73.33	45.1844	15.30524
2	*Pretest B*	18	23.33	70	44.8161	13.82501
3	*Posttest A*	18	33.30	83.30	58.3222	14.87511
4	*Posttest B*	18	40	90	62.5928	16.43266
5	*Pretest AB*	36	20	73.33	45.0003	14.37528
6	*Posttest AB*	36	33.30	90	60.4575	15.59877

Based on Table 18, the minimum value, maximum value, average, and standard deviation of the pre-test and post-test of groups A and B can be obtained.

Normality Test

The normality test is the next stage of descriptive analysis to check whether the data is normally distributed. There are two types of normality tests: the Kolmogorov-Smirnov and Shapiro-Wilk. Both tests are considered normal when the significance value is > 0.05 (Table 19).

Table 19. Data Normality Test

No.	Data	*Shapiro-Wilk*		
		Statistic	df	Sig.
1	*Pretest A*	0.970	18	0.732
2	*Pretest B*	0.955	18	0.504
3	*Posttest A*	0.963	18	0.651
4	*Posttest B*	0.928	18	0.180
5	*Pretest AB*	0.970	36	0.415
6	*Posttest AB*	0.959	36	0.202

Using the Shapiro-Wilk test, the normality test found the pre-test and post-test data results for each group with a significance value of> 0.05; it can be concluded that the data is normally distributed.

Homogeneity Test

The homogeneity test in the next stage after the normality test aims to see whether the data analyzed is similar. The data value requirement is said to be homogeneous when the sig value. > 0,05 (Table 20).

Table 20. Homogeneity Test Result

No.	Data	Levene Statistic	df1	df2	Sig. (2-tailed)
1	*Pretest AB*	0.073	1	34	0.789
2	*Posttest AB*	0.556	1	34	0.461

Based on Table 20, the pretest AB and posttest AB data were obtained with a significance value> 0.05. It can be concluded that the data is homogeneous because it has met the specified requirements.

Paired Samples T-Test

After the data underwent a normality test and homogeneity test, a paired samples t-test was conducted to evaluate the changes in each group, with the condition that the significance value <0.05 (Table 21).

Table 21. Paired Samples T-Test Result

No.	Data	t	df	Sig. (2-tailed)
1	*Pretest A - Posttest A*	-9.302	17	.000
2	*Pretest B - Posttest B*	-8.244	17	.000

Table 21 shows a significant effect because the significance value is <0.05 on student learning outcomes using learning media.

Dissemination of Product Development Results

The distribution of the developed product is the final series of all stages that have been carried out. Interactive learning media can be distributed by accessing the printed guidebook. The distribution of mini books to schools aims to be well utilized as a learning tool by teachers.

Figure 11. 3D Hologram Product Dissemination

The results of making products are through the stages of making illustrations, making media, making questions, and making guidebooks. The products made are then assessed by media experts, material experts, linguists, students, and teachers. Products that are suitable for use as interactive learning media are tested for effectiveness. This effectiveness test was conducted by dividing the number of State Elementary School 3 Jambu students and State Elementary School 1 Banteran into control and treatment groups.

Based on the results of research, the application of hologram media has a positive impact on students, including increasing their interest in learning and fostering a higher interest in education (Hasyim, 2019; Awi et al., 2023; Sari et al., 2023). Meanwhile, according to Wahyudi (2018), three-dimensional hologram videos can improve students' learning achievement compared to traditional learning methods. The use of interactive hologram media in learning sports games also received positive responses and enthusiasm from students, marked by increased learning outcomes.

The results of other studies show that the design of learning media can improve student learning outcomes by applying the learning media provided (Sholiqah & Agustina, 2019). According to Harsiwi & Arini (2020), in general, using learning models through interactive media can motivate students, which then contributes to improving their learning achievement, as reflected in students' positive responses to these models. The existence of interactive learning media is expected to motivate students so that it has an influence on improving their abilities and positive learning outcomes (Vebrianto et al., 2023).

Various journals have extensively studied the effectiveness of interactive learning based on hologram technology. Research has shown that hologram-based learning can positively impact student learning outcomes, including improved knowledge retention, increased motivation, and enhanced spatial awareness. Studies have also shown that hologram-based learning can be particularly effective in science, technology, engineering, and mathematics (STEM), where complex concepts and spatial relationships are often difficult to visualize. For example, a study published in the Journal of Educational Multimedia and Hypermedia found that students who used hologram-based learning materials significantly improved their understanding of complex scientific concepts compared to traditional learning materials (Yu et al., 2024). Another study published in the Journal of Science Education and Technology found that hologram-based learning can increase student motivation and engagement in STEM subjects, particularly among traditionally underrepresented students in these fields (Rakha, 2023). Overall, the evidence suggests that hologram-based learning can be a highly effective tool for improving student learning outcomes, particularly in subjects that require complex spatial visualization and understanding.

Based on responses from teachers, this learning media is made of elementary school materials and crucial because it shows students' enthusiasm for the learning process. Responses: Students are happy to use hologram-based learning media and have just used it as an interactive learning media. Teachers can use hologram video learning media for independent learning at home because an evaluation is provided for each material. Based on the results of this study, hologram-based interactive media development products received a very feasible category based on the assessment of media experts, material experts, linguists, students, and teachers. The effectiveness test results show that the data is normally distributed and homogeneous, significantly influencing student learning outcomes.

However, this study has several limitations. First, the sample size was limited to two elementary schools, which may not fully represent the broader student population. Future research should expand the sample size to include students from diverse geographical locations and different educational backgrounds. Second, the study primarily focused on cognitive learning outcomes, while aspects such as long-term retention, critical thinking, and collaborative learning were not deeply explored. Future studies should investigate these additional factors to provide a more comprehensive understanding of the effectiveness of hologram-based learning. Lastly, the study did not analyze the cost-effectiveness

of implementing hologram technology in education. Future research should examine the feasibility and sustainability of integrating hologram-based learning on a larger scale.

Based on these findings, future research should explore the application of hologram-based learning in different subject areas beyond physical education, such as language learning and social sciences. Additionally, investigating the integration of hologram technology with other interactive tools, such as augmented reality (AR) and virtual reality (VR), could provide new insights into optimizing digital learning environments. Educators and policymakers should consider developing training programs for teachers to enhance their ability to implement hologram-based learning effectively in classrooms.

Conslusions

Based on the analysis and discussion of interactive learning media for sports material for large and small ball games, 3D Hologram interactive media development results suit elementary/equivalent school students in helping students understand PE learning material. The effectiveness test results on the paired samples t-test of the treatment group show an increase in learning outcomes after students use 3D Hologram learning media. The development of this interactive learning media is a recommendation for developers of other similar learning materials.

Further research recommends developing 3D Hologram learning media at higher education levels and on different learning materials. In addition, it can also compare the effect of using learning media with other media to improve students' cognitive, affective, and psychomotor aspects through physical education learning.

Authors' contributions

SWL, DRB and RF was responsible for data collection, analysis, article design, writing, and revision. K, EOS and MAK were responsible for the article's conceptualization and conducted a rigorous and critical manuscript revision. All authors have read and approved the final manuscript.

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Competing interests

The authors declare no competing interests.

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