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Development of Android-Based Interactive Mobile Learning with Guided Inquiry Models to Improve Higher Order Thinking Skills on Light Wave Material

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Abstract: This research aims to produce Android-based interactive mobile learning with a guided inquiry model of light wave material that is able to improve students' HOTS abilities. This research is a 4D model type research. The research was conducted at MAN 1 Ponorogo, MAN 2 Ponorogo, and SMAN 1 Badegan. The research subjects were 149 class XI MIPA students who gave a pretest-posttest. Student pretest-posttest data were analyzed using 1-way ANOVA to determine the differences in students' HOTS skills in the control and experimental classes. Based on the 1-way ANOVA test, it was found that there were differences in students' HOTS abilities in the two classes. Classes that use Android-based interactive car learning get higher results compared to classes that don't use Android-based interactive car learning.

Keywords: Android-based interactive mobile learning; Guided inquiry learning; Higher order thinking skills (HOTS); Light wave

Introduction

Increasingly tight global competition requires individuals to dominate 21st century skills. These skills include critical thinking and problem solving. These two skills are included in HOTS skills. HOTS skills do not only include critical thinking and problem solving skills, but include all activities to be able to think more deeply about everything. The HOTS ability can enable students to observe all related phenomena, make students critical in looking at various problems, and can help someone to be able to develop new ideas for the problems they face. Individuals who have competent HOTS skills will have a positive impact on their learning outcomes (Ramos et al., 2013). Therefore HOTS provides many benefits for students. Students have creative, innovative, reflective abilities, can solve problems, and can make good decisions. However, student learning outcomes at the cognitive level are low. Thus students' HOTS skills need to be improved.

Students' HOTS abilities are still low. Based on the research results of Bilqis et al. (2021) concluded that students' HOTS abilities on analytical indicators are still low. Students also experience problems in reviewing the content of the material which results in difficulties in solving complex problems so that students' HOTS abilities are low (Sari & Slamet, 2019). This data provides information that students' HOTS scores are not good and need to be improved. Students think that existing problems are difficult to solve. This shows that there is a lack of controlled learning that trains higher level thinking. The efforts made by previous researchers were using interactive learning media and training students with HOTS-oriented questions.

The HOTS ability of students in physics material is still low. Based on the analysis of the results of the National Examination scores, the HOTS ability of physics students in Ponorogo was 42.41 and was included in the less category. Students assume that the existing problems are difficult to solve. So that students

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have difficulty solving complex problems. Physics material that students consider difficult includes light waves (Kaltakci-Gurel et al., 2016; Nasir et al., 2021). Based on research by Dido et al. (2021), it can be concluded that students still have problems understanding light refraction, such as drawing the angle of incidence, direction of refraction, and position of refraction for two different media. Another difficulty that is often encountered is that students only tend to use a geometric optical approach in analyzing light wave phenomena. Students usually think that if the left slit in a double-slit interference experiment is closed, then the left pattern formed on the screen will disappear because each slit is responsible for half of the interference pattern (Dai et al., 2019). Students also tend to think that the smaller the width of the single slit, the narrower the bright pattern formed on the screen will be. This is due to misconceptions about physics material (Mešić et al., 2019). Therefore, physics material, especially light waves, is used in this research to help students solve difficult problems correctly.

Based on the results of initial studies and interviews at MAN 1 Ponorogo, MAN 2 Ponorogo, and SMAN 1 Badegan, it shows that learning activities have not fully encouraged students to be active. Many students are passive during learning activities, some are chatting with their friends and some are playing on their cellphones. When students are asked questions by the teacher, they answer with the word "understand", but when given questions after learning the students have difficulty solving them.

The learning media used by teachers is still manual so its usefulness is very limited, so there is a need for digital media innovation by utilizing Android which is easily accessible from various places so that its usefulness is wider (Aji et al., 2020; Anshari et al., 2017). The use of technology provides many benefits in learning, including strengthening, stimulating and motivating students in learning (Hochberg et al., 2018; Ubben et al., 2023). One technology that is widely used is smartphones. Smartphones consist of many features that can help students learn if used appropriately (González et al., 2017; Tossell et al., 2015). However, many students use smartphones for social media and entertainment so their usefulness is relatively low. Facts in the field show the same thing that the use of smartphones is not optimal and consistent to support learning. Therefore, it is necessary to direct the use of smartphones to access learning resources and media so that their usefulness is higher.

Using an Android smartphone for studying has several disadvantages. These weaknesses are that the display presented on an Android smartphone is smaller and the storage memory on a smartphone is less than a laptop. Therefore, before developing an Android-based product, it is necessary to look at its weaknesses as well. Efforts that have been made by previous researchers to fix the problems that arise are using Android-based mobile learning to improve students' HOTS abilities. Learning with mobile learning enables students to be able to solve various complex problems.

Based on the explanation above, a solution is proposed to overcome existing problems by developing a product in the form of Android-based interactive mobile learning to improve HOTS capabilities and collaboration skills. The media is created based on an Android smartphone and is interactive. This allows students to learn easily and more interactively. The media facilitates students to be able to develop HOTS abilities through the analysis and evaluation process related to light wave material. Media also facilitates students to work together with other individuals in the form of collaboration in achieving learning goals so as to develop students' collaboration skills. Learning media is implemented with a guided inquiry learning model which makes students active in learning.

Method

This research was conducted at MAN 1 Ponorogo, MAN 2 Ponorogo, and SMAN 1 Badegan in class XI MIPA. This research aims to produce an Android based interactive learning car with light wave material. This research uses the Research and Development (R&D) method. The R&D method is a method that is able to produce certain product designs and develop them by testing the validity of the product so as to produce products that have been tested and can be widely used (Sugiyono, 2020).

The subjects in this research were 149 class XI MIPA students from three schools. The research instrument consisting of material packaged in Android-based interactive mobile learning, learning implementation plans, student worksheets, and HOTS question instruments was validated by two experts.

Result and Discussion

Feasibility Assessment Results and Validation

The results of the feasibility assessment of Android-based interactive mobile learning by material experts are shown in Table 1. Based on the assessment by material experts it can be seen that the material contained in android-based interactive mobile learning is at very feasible criteria.

The feasibility assessment of Android-based interactive mobile learning by media experts is shown in Table 2. Based on the assessment by media experts, it can

be seen that Android-based interactive mobile learning is in very feasible criteria.

Table 1. Results of Material Feasibility Assessment in Products by Material Experts

Assessment Aspects	Validator Score I	Validator Score II	Average	Criteria
Learning	4.00	3.85	3.92	Very feasible
Material	4.00	3.75	3.88	Very feasible
Average			3.90	Very feasible

The results of the feasibility assessment and validation of the learning implementation plan, student worksheets, and the HOTS question instrument are shown in Table 3. Based on the assessment results it can be seen that the learning implementation plan and student worksheets are in very feasible criteria. In addition, based on the results of the validation it is known that the HOTS question instrument is in the valid criteria. This is because the V-Aiken index value obtained is > 0.8 (Istiyono, 2020).

Table 2. Results of Product Feasibility Assessment by Media Experts

Assessment Aspects	Validator Score I	Validator Score II	Average	Criteria
Software engineering	4.00	3.75	3.88	Very feasible
Ease and flexibility in access	4.00	3.83	3.92	Very feasible
Presentation	4.00	3.75	3.88	Very feasible
Visual communication	4.00	3.60	3.80	Very feasible
Interactivity	4.00	3.50	3.75	Very feasible
Average			3.84	Very feasible

Table 3. Results of Feasibility Assessment and Validation of Learning Implementation Plans, Student Worksheets, and HOTS Question Instruments

Product	Assessment Aspects	Validator Score I	Validator Score II	Average	Criteria
Lesson plan	Identity; formulation of competency achievement indicators; formulation of learning objectives; learning materials; selection of learning methods, models, and media; learning activities; learning resources; assessment of learning outcomes; and language	4.00	3.86	3.93	Very feasible
Student worksheet	Adequacy of content, presentation, and language	4.00	3.91	3.95	Very feasible
HOTS question Instrument	The question, construction, and language indicators			0.99	Valid

The results of the assessment found that there were several suggestions for improvement from experts regarding the product being developed. The suggestions submitted by experts are shown in Table 4.

The product developed was improved according to the suggestions from the validator. The final product that has been repaired is shown in Figure 1.

Table 4. Product Improvement Suggestions from the Validator

Product	Validator's Suggestion
Android-based interactive mobile learning	Standardize the writing of quantities and units.
	Enlarge the image to see clearly.
	Complete the image source used in the material.
	Add some explanations so as not to cause misconceptions.
	Combine the "Reflection" menu and the "Refraction" menu into one as well as the material.
	Do a test on various devices so that it looks good.
	Clarify interactive intent in learning.
	The material presented is quite complete if you can add pictures to make it easier for students to understand the material.
HOTS question instrument	Correct writing errors in sentences.
	Add related information to the problem image so that the meaning of the question is clear.

Figure 1. Display of android-based interactive mobile learning

Limited Test Results and Empirical Tests

The limited test results for the legibility of Android-based interactive mobile learning are shown in Table 5. Based on the results of the limited test, it can be stated that Android-based interactive mobile learning is easy to read and practical to use.

Table 5. Limited Media Test Results

Assessment Aspects	Score	Criteria
Fill	3.83	Very feasible
Presentation	3.86	Very feasible
Graphic	3.81	Very feasible
Language	3.85	Very feasible
Average	3.84	Very feasible

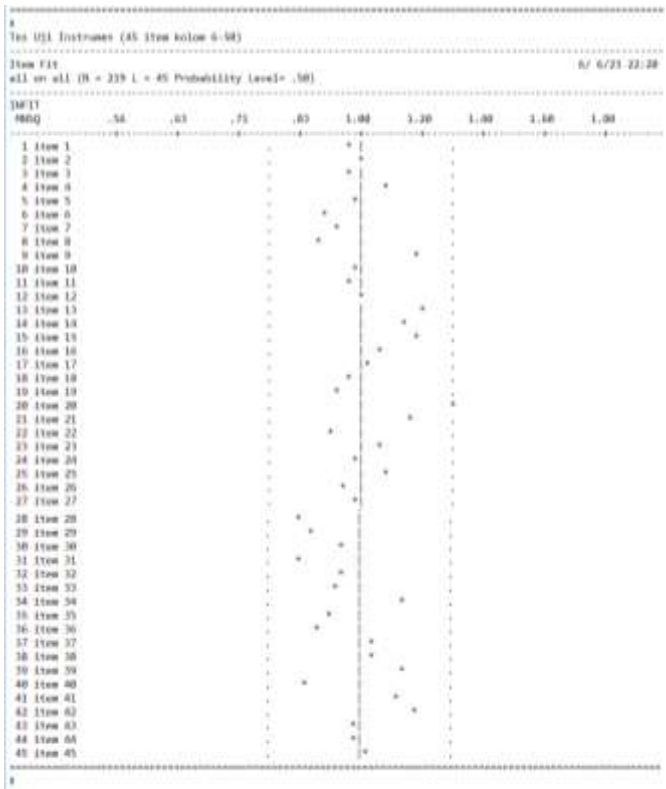

Figure 2. HOTS question instrument validation results

The empirical test results of the HOTS test instrument are shown in Figure 2. The validity of the items can be seen from the output of the QUEST program, namely the INFIT MNSQ section. The INFIT Mean Square (INFIT MNSQ) used in this study is in the range of 0.77-1.30 (Adams & Khoo, 1996: 30). Based on these results it can be seen that all items fit the Rasch model, so it is said to be valid.

The results of the HOTS test instrument reliability test are shown in Table 6. Based on reliability by Subali & Suyatna (2011: 11) the instrument is declared reliable if it is in the range of 0.60-1.00. So the HOTS question instrument used in this study is reliable criteria.

Table 6. HOTS Item Reliability Test Results

Reliability	Reliability Coefficient
Summary of item estimate	0.70
Summary of case estimate	0.96

Field Test Results

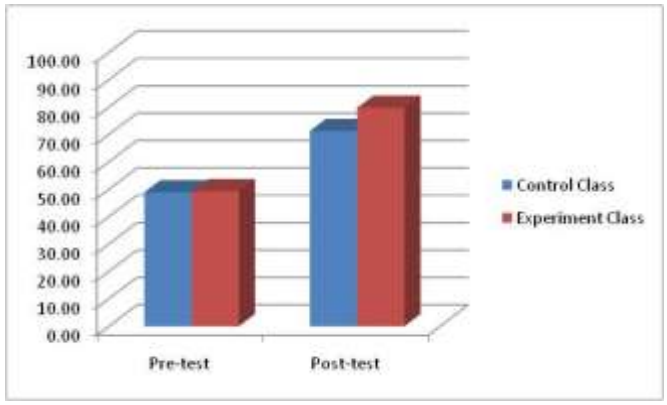

Figure 3. HOTS ability pretest-posttest results

The field test was conducted using 2 classes from 3 different schools (MAN 1 Ponorogo, MAN 2 Ponorogo, and SMAN 1 Badegan). One class was the control class and another class was the experimental class. Analysis was carried out on the effectiveness of the product in increasing the HOTS ability of light wave material. The

results of the descriptive statistical test for students' HOTS abilities are shown in Figure 2. Based on these results it can be seen that the average HOTS ability of students before being given treatment (pre-test) is still low. While after being given the treatment (post-test) students' HOTS abilities experienced a higher increase in the experimental class.

The results of students' HOTS abilities on each indicator can be seen in Figure 4. Determining the criteria for the results of the assessment.

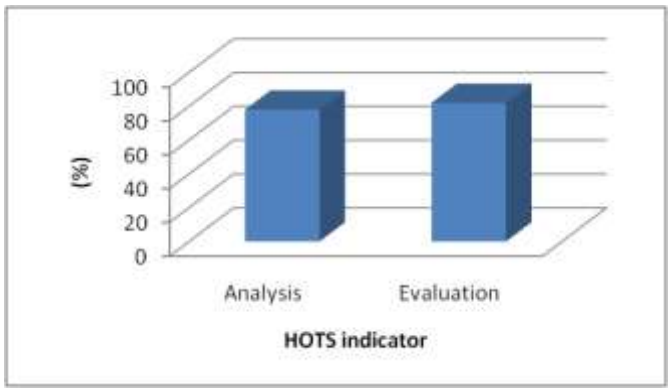

Figure 4. HOTS capability results from each indicator

Based on these results it is known that the highest result is in the evaluation indicator with a score of 82% which is included in the very good criteria and the lowest score in the analysis indicator is 78% which is included in the good criteria.

Students' HOTS abilities can be increased influenced by several things contained in Android-based interactive mobile learning, and assessment instruments. The application of this media allows students to explore higher-order thinking skills by trying to find out the physics material they are studying and training students' abilities to solve complex problems (Dasilva & Suparno, 2019; Mardiana & Kuswanto, 2017).

Android-based interactive mobile learning provides a major role in improving students' HOTS abilities. The media is packaged by utilizing various features that make the media interactive. The material contained in the media is packaged in a simple but attractive manner because there are pictures, videos, and simulations that support learning. Through videos and simulations, it is easier for students to master physics concepts (Chasanah et al., 2019). Apart from the material, there are HOTS questions presented in the media. Through these questions, students can find out their level of ability to solve problems in each sub-discussion of the material.

Learning activities packaged in media are integrated with the guided inquiry learning model. At the beginning of the activity, videos and pictures were presented which became a trigger for students to find solutions to existing problems. Through the presentation of the problem, students are asked to formulate a problem. Furthermore, students are asked to carry out investigative activities through the simulation features contained in the media. This activity encourages students to explore the phenomena of light waves. Interactive features in the media get a positive response from students.

Interactive features make the media controllable by the user and provide feedback, as in the simulation section. The simulation of the phenomenon of light waves presented can be controlled by the user by adjusting the quantities contained in it. The media provides feedback by responding to the treatment given by the user. Through this exploration with interactive media, students demonstrate HOTS ability processes, namely being able to give reasons for a problem that arises, think critically, and be able to make decisions and find solutions (Puspita et al., 2020).

Media that is designed to be interactive has been proven to be able to increase students' cognitive achievements. This is in line with the results of Cynthia et al. (2023) research that students' ability to think critically increases. Apart from that, the interactive media developed is also able to make science lessons such as physics more interesting (Festiyed et al., 2023; Utamingsih et al., 2023). Therefore, the use of interactive media has many benefits and is effectively used in learning.

Analysis of product effectiveness in improving HOTS abilities that have been implemented based on students' post-test scores. The analysis was carried out using 1-way ANOVA on student scores. One-way ANOVA is used because it can analyze data based on the difference in the average parameters of two or more sample groups (Kadir, 2018). Before the post-test student data were analyzed using one-way ANOVA, a prerequisite test was carried out first to determine the normality and homogeneity of the data. The prerequisite test results are shown in Tables 7 and 8.

Table 7. Normality Test Results

		Mahalanobis Distance	Chi
Mahalanobis distance	Pearson correlation	1	.99**
	Sig. (2-tailed)		.00
	N	149	149
Chi	Pearson correlation	.99**	1
	Sig. (2-tailed)	.00	
	N	149	149

The results of the normality test can be seen by looking at the significance value in Table 7. Based on these results by looking at the relationship between the Mahalanobis distance and the chi-square, it can be obtained that the significance value is 0.00 < α = 0.05. So it can be concluded that the post-test data comes from normally distributed samples. The homogeneity test results can be seen in Table 8.

Table 8. Homogeneity Test Results

		Levene Statistic	df1	df2	Sig.
Posttest	Based on mean	.13	1	147	.71
	Based on median	.03	1	147	.86
	Based on the median and with adjusted df	.03	1	146.11	.86
	Based on trimmed mean	.10	1	147	.75

Based on Table 8 it can be seen that the significance value of the two-tailed sig. > α = 0.05. So it can be said that the student post-test data is homogeneous. A one-way ANOVA test was conducted to explain differences in students' HOTS abilities between students who studied using and without the developed product. The difference indicates that the product is effective for use. The results of the ANOVA test are shown in Table 9.

Table 9. ANOVA Test Results

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	2678.06	1	2678.06	65.89	.00
Within groups	5974.16	147	40.64		
Total	8652.22	148			

The significance value obtained was 0.00 < α = 0.05, so it can be concluded that there were significant differences in students' HOTS abilities in both classes. In more detail, to find out the difference in students' HOTS abilities in the two classes, a pairwise comparisons test was carried out. The test results are shown in Table 10.

Table 10. Pairwise Comparisons Test Results

(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig. [b]
Control	Experiment			
Experiment	Control	8.48*	1.04	.00

Based on the results of the pairwise comparisons test, a significance value of 0.00 < α = 0.05 was obtained. So it can be stated that there is an influence of Android-based interactive mobile learning on students' HOTS abilities between the control and experimental classes. Furthermore, to determine the level of effectiveness of the product being developed, an effect size test was carried out. The test results are shown in Table 11.

Table 11. Effect Size Test Results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	2678.06[a]	1	2678.06	65.89	.00	.31
Class	2678.06	1	2678.06	65.89	.00	.31

Based on Table 11, the partial eta squared value obtained is 0.31, this shows that android-based interactive mobile learning has a great influence on students' HOTS abilities. This value is included in the high donation criteria > 0.14 (Miles & Shevlin, 2001).

Good learning conditions are created due to the application of Android-based interactive mobile learning with a guided inquiry learning model. Learning media using Android can improve students' HOTS skills (Ali & Zaini, 2023). Apart from that, the use of Android is also able to enable students to understand the material more deeply so that learning is more meaningful (Rosidah et al., 2021; Susanto et al., 2022). The guided inquiry learning model is a teaching approach where the teacher presents specific material topics and guides students in understanding and finding solutions. Students are guided through the work steps on the student worksheet contained in the media. The final results show that students can be helped in carrying out investigative activities. Another condition created is that it can train students' abilities to reason or think more deeply so that students' HOTS abilities become better. The media developed can make it easier for students to dig up information, help students understand concepts and solve complex problems.

Conclusion

Based on the results of research regarding the developed android-based interactive mobile learning with guided inquiry learning is suitable for use in improving students' HOTS abilities in light wave material. Based on the inferential statistical test using 1-way ANOVA, obtained a significance value of 0.00. This value indicates that there are differences in students' HOTS abilities between those who use Android-based interactive mobile learning and those who do not use it in the control class. Further results using partial ETA squared obtained a significance value of 0.31 which is in the high criteria for the effect of using Android-based interactive mobile learning.

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Research design and concept, S. M and S; field investigation and analysis, S. M; writing and drafting S. M and S; Editing, S.

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Conflicts of Interest
The authors declare no conflict of interest.

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