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Development Modul Guided Inquiry Integrated Augmented Reality (M-GIIAR) to Improve Student's Science Process Skills on Mechanical Wave Material

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ABSTRACT

Science learning skills need to be applied at every stage of learning. However, students do not have good science process skills (SPS). Learning media is also needed to support modern and engaging science learning skills. Research using the ADDIE model, a sample of 30 students in class XI MIPA at SMAN 1 Wanayasa. The average validity test results are 82.40%. The results of implementing Authentic assessment based on Teaching and Learning Trajectory with Student Activity Sheets increased from each meeting; the average value was 85.58% with good effectiveness. The results of the N-Gain pretest and posttest based on the science process skills indicator obtained an average N-Gain result of 0.57 with a moderate interpretation. The researcher used a nonparametric hypothesis test with the Wilcoxon sign rank type. The results of the hypothesis test obtained acceptance of the alternative hypothesis (Ha), meaning that there was an increase experienced by students in SPS in mechanical wave material. Based on several aspects, student responses obtained an average of 70.07% in the good and positive category.

Introduction

The teacher acting as a facilitator must be able to guide students so that they can easily understand the material presented through learning styles that are in accordance with the current conditions of digital technology and the ability of students to process learning material (Rahmawati & Suryadi, 2019). Through media and learning models, the teacher can manage the material well. Several learning models are commonly applied to teaching and learning, one of which is a learning model that can sharpen the process of inquiry or inquiry, especially in achieving Science Process Skills (SPS).

Based on the results of observations in one school by interviewing a physics teacher and giving questionnaires to students, the average interview result was 49.4% or the moderate category, meaning that further follow-up is needed to improve learning. The moderate category is that the science learning model does not yet meet the stages of science, and the use of learning media does not support the science process model. Schools for interviewing a trial are not the same, but they have criteria about students, and physics learning conditions are the same. Printed books still dominate the learning media without being integrated. Based on the results of observations at school regarding learning conditions in science process skills through the SPS test with ten SPS dimensions, namely observation, classification, interpretation, prediction, asking questions, formulating hypotheses, planning, using tools/materials, applying concepts, communicating, the medium category was obtained with the average is 5.64. As for the results of interviews with teachers, the medium category was obtained with a percentage of

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49.9% in the teaching and learning model using SPS. In the research by Maulidhatul Rahma et al. (2020) and Nainggolan and Tampubolon (2022), the level of SPS ability of high school students in learning physics is still considered low.

Solving problems with the science process can fulfill several science process skills indicators, according to Rustaman (2005), consisting of ten indicators, namely observing, classifying, interpreting, predicting, posing problems, formulating hypotheses, planning experiments, using tools and materials (sources), implementing concepts, and communicating (Sari et al., 2019; Yati Lestari et al., 2018). Learning models and media are needed to improve science process skills (Khotimah et al., 2019). One is through the guided inquiry learning model, following scientific inquiry (Abriani et al., 2016). In the 21st century, learning media integrated with technological sophistication is needed. Augmented reality is currently being developed (Imas Masitoh et al., 2021).

Learning media is a set of tools used to distribute learning material. Examples of learning media are books, modules, videos, tapes, posters, etc. Based on the results of a study conducted by Bangun et al. (2019) at SMAN 3 Banjarmasin regarding increasing SPS in high school students by developing guided inquiry-based modules, there was an increase in SPS from initially being in the low to medium category with the implementation of the guided inquiry module. The use of modules can be an alternative learning media other than books because the discussion of the material focuses on one basic competency, with a deeper explanation and a more straightforward physical form than a book (Angriani et al., 2020).

Technology in learning media can positively affect the acceptance of learning material (Yaumi & Damopolii, 2019). According to Garzón et al. (2020), today's students are responsive in empowering and operating technology. This character becomes an opportunity in the learning process. Augmented reality is a technology that shows an abstract object to be more accurate or can be in the form of 2D and 3D. AR can be implemented in education so that students are motivated and passionate about learning (Garzón et al., 2020; Hakim, 2018). Irmi et al. (2019) researched applying the guided inquiry model with the help of QR codes to improve science process skills. Augmented reality illustrations in this research use the help of the Assemblr World application or website. To view augmented reality illustrations, you can scan the quick response code (QR Code) as a marker for the illustration in the Assemblr World application. It was found that there was a difference in the increase in science process skills in the control and experimental classes after treatment (Firmansyah et al., 2023). At the observation of the SPS stage, AR can be used for students to observe abstract illustrations so that they look concrete. So students can analyze events and shapes by observing the illustrations displayed in AR.

The willingness of students to learn is essential so they do not feel forced and comfortable in the learning process. Through fun and up-to-date learning, media as a bridge for introductory material can provide a sense of willingness to learn (Pramudya et al., 2023). Khunaeni et al. (2020) conducted research regarding physics learning modules with the help of Augmented Reality technology on sound wave material. Mechanical wave material is closely related to the structure and properties of abstract waves. Therefore, it is necessary to concretely depict the nature and structure of waves. AR technology is a supporting medium that provides a detailed understanding of mechanical waves. The results show that the module is feasible to implement and that the student response is very good regarding learning outcomes. The novelty of this research is using a module with step-of-science process skills in the form of a printed mechanical wave material module with the help of a QR Code as a marker to create augmented reality for each mechanical wave illustration.

This study aims to analyze the improvement of science process skills with integrated augmented reality-guided inquiry modules on mechanical wave materials. Through the validity of the module to be tested for feasibility before implementation, knowing its implementation and the results of students' responses to Development Modul Guided Inquiry Integrated Augmented Reality (M-GIIAR) after being applied to the learning process. This research was conducted at SMA Negeri 1 Wanayasa for students in class XI MIPA.

Methods

This study used a mixed method approach, with a pre-experimental method with design one group class pretest and posttest. A qualitative approach is used to find out the problems and needs and the feasibility of modules and questionnaires of student responses from the results of questionnaires and interviews. As for the quantitative approach through statistical calculations (Murdianto & Astuti, 2021). The research was conducted using the Pre-experimental research method with a one-group pretest-posttest Design research design. According to Fraenkel & Wallen (2009), this method is usually used in educational research to test the teaching materials or media used.

Development research is a type of Research and Development (RnD) research (Nabilla et al., 2021). This type of RnD research can be used to make a product more effective or maximize an old product so that it can be used in the modern era (Muqdamien et al., 2021).

This type of research is research and development with the ADDIE model (analysis, design, development, implementation, evaluation). The ADDIE model stage, which consists of five stages, is a research stage developed by Robert M. Branch, which includes five stages of development: research, analysis, designs, development, implementation, and evaluation. This research data sources come from two data, namely primary data in the form of data generated from field collection during interviews of teachers and students, validation with validation sheets about modules and learning models of guided inquiry, and implementation of modules made previously in the school. Secondary data comes from literature studies from books, websites, and research articles.

The research process was carried out using the ADDIE model stages. 1) Analysis by conducting a preliminary study through interviews with physics teachers and observing SPS questions. 2) Design, making SPS pretest and posttest question instruments, lesson plans, media, material expert validation sheets, and Integrated Augmented Reality Guided Inquiry Module. 3) Development, validating the eligibility of the question instrument, as well as the eligibility of M-GIIAR for media and material experts. 4) Implementation, through SPS pretest and posttest questions, using authentic assessment based on teaching and learning trajectory (AABTLT) with student activity sheets (SAS) at each meeting. 5) Evaluation by analyzing data on validity results, pretest and post-test results, learning implementation, and students' responses to the module (Ariama et al., 2022; Ofosu-Asare et al., 2019; Ryazanova et al., 2021).

The stage of this research using data collection techniques was carried out using instrument questionnaires, open interviews with physics teachers, distribution of observation questionnaires to students about the science learning process, learning model and use of learning media, and SPS observation questions with ten indicators SPS. Validate learning media using instrument sheets consisting of standard rules of learning modules based on technology augmented reality and standard rules of guided inquiry learning models. Validation assessment techniques are used with a Likert scale, and media and material experts provide commentary suggestions. Pretest-posttest question sheets, based on research by Maulida et al. (2018), authentic assessment with Authentic assessment based on Teaching and Learning Trajectory (AABTLT) with Student Activity Sheets (SAS), assessment using this instrument according to research by Putri (2017a) is more effective. A student response questionnaire was also used after using M-GIIAR on mechanical wave material. The population in this study were students of SMA Negeri 1 Wanayasa class XI MIPA. The sample selection was carried out using a purposive sampling technique, based on the number of students in the class. The research sample was class XI MIPA 4, with as many as 30 students.

To calculate the result of the learning process with AABTLT with SAS-associated science process skills, use average results from stages guided inquiry learning model and ten indicators SPS, such as Equation 1. The criteria for learning outcomes are shown in Table 1.

$$X = \frac{a}{b} x\ 100\% \quad (1)$$

Information:
a : total score for each learning stage of the guided inquiry model
b : total score maximum from each learning stage

Table 1
Criteria of Learning Outcome

Average Percentage of Learning Outcomes (%)	Criteria
$\boldsymbol{X} <55$	Ineffective
$55 \leq \boldsymbol{X} \leq 70$	Less effective
$70 \leq \boldsymbol{X} \leq 85$	Effective
$\boldsymbol{X} > 85$	Very effective

The data analysis technique uses the mix-method, on the item validation sheet with a reliability test, difficulty test, discriminating power test and test item validity, using anates. With this type of exploratory design, qualitative data collection, namely interviews and quantitative SPS tests, in this case, qualitative and quantitative, provides a supporting, secondary role in research-based primarily on quantitative data. Both data are interrelated to support data processing, and results are analyzed qualitatively for instrument validation results with quantitative Excel calculations, as in Equation 2.

$$\bar{x} = \left(\frac{\sum f_i x_i}{\sum f_i}\right) x100\% \quad (2)$$

Information:
f_i : indicator frequency
x_i : the value of each indicator

Interpretation of Feasibility is shown in Table 2.

Table 2
Interpretation of Feasibility

Score	Score range (%)	Criteria
5	$80 \leq \bar{x} \leq 100$	Very worthy
4	$60 \leq \bar{x} < 80$	Worthy
3	$40 \leq \bar{x} < 60$	enough
2	$20 \leq \bar{x} < 40$	Middle worthy
1	$0 \leq \bar{x} < 20$	Not worthy

(Arikunto & Suharsimi, 2009)

The results of suggestions and comments using qualitative analysis. Analyze implementation results with quantitative Excel calculations at each meeting. Analysis of the pretest-posttest results of SPS questions by determining the N-Gain formula, as Equation 3. Criteria of N-gain are shown in Table 3.

$$N\ Gain = \frac{posttest\ score - pretest\ score}{ideal\ score - pretest\ score} \quad (3)$$

Table 3
Criteria of N-Gain

N-Gain	Interpretation
g < 0,30	Low
0,30 ≤ g ≤ 0,7	Medium
g > 0,7	High

(Mardatila et al., 2019)

Use the Kolmogorov Smirnov test for the normality test, as Equation 4.

$$D = \max(F(Y_i) - \frac{i-1}{N}\frac{i-1}{N} - F(Y_i) \quad (4)$$

Hypothesis testing with the Wilcoxon rank test with formula as Equation 5.

$$Z = \frac{T-\sigma_T}{\sigma_T} = \frac{T-\frac{N(N+1)}{4}}{\sqrt{\frac{N(N+1)(2N+1)}{24}}} \quad (5)$$

Information:
T : The number of rankings is marked as small
N : The number of pairs with different values

The results of the student response questionnaire analysis with Excel calculations are quantitative. In line with the research of Bangun et al. (2019), the research instrument is a module that is tested for feasibility validation, and the results of the increase with pretest and posttest are presented.

Result and Discussions

The results of the research that has been carried out based on the research instruments that have been made are as follows:

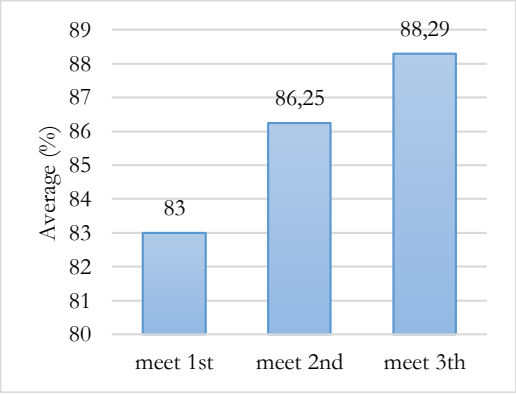
The Test Validity of the Module Guided Inquiry Integrated Augmented Reality

Module validity test is obtained from two aspects, namely material and media aspects. The validity test results by media and material experts consisted of four media experts and three material experts, regarding the M-GIIAR validity test results obtained from the average media results of 84.63%. The validation aspect uses a media validation sheet with 27 indicators given to four media experts and a module view. As for the material aspects, the average is 80.17%, with as many as 40 indicators covering the material in the module and completeness in terms of language and material. The two aspects of the validation test assessment obtained an average value recapitulation of 82.40%. If interpreted based on the validation test results, the module is included in the very feasible category. Based on the results of the validation test recapitulation from the media and material aspects, it can be seen that the results of media experts have a higher average score than the material aspect. However, both are still in the very decent category. The results of this validation test align with the research of (Khunaeni et al., 2020).

Results in the Learning Process Stage of Guided Inquiry Learning Models

The learning implementation was carried out in three meetings. At each meeting, the recapitulation results obtained at each meeting are shown in Figure 1 as proof of the implementation of M-GIIAR with science process skills can be applied using AABTLT with SAS.

Figure 1
Average Recapitulation AABTLT from Three Meetings in Learning



The results of the implementation of the use of M-GIIAR on mechanical wave material with its association with SPS are obtained. The average recapitulation results from the three meetings is 85.85% in the very effective category. In Figure 1, it can be seen that there is an increase at each meeting. This means there is an increase in SPS at each stage of guided inquiry using M-GIIAR in the learning process. So, it can be evidenced that the SPS learning process can be carried out using the AABTLT with the SAS instrument to support the inquiry-guided learning model. The implementation results align with Putri (2017b) with a practical category value.

Improvement of Science Process Skills Before and After the Application of M-GIIAR with Pretest and Posttest

Science process skills can be measured using pretest and posttest. According to the number of SPS indicators, the pretest and posttest consist of 10-item description questions. The pretest was given at the first meeting, and the posttest was given at the end of the research meeting. Table 4 provides an analysis of improvement by analyzing the value of N-Gain.

Table 4
The Results of the Score N-Gain Pretest and Posttest

Indicator SPS	Question Number	Pre-test	Post-test	N-Gain	Category
Observation	1	54	92	0,77	High
Classification	2	74	81	0,23	Low
Interpretation	3	52	92	0,78	High
Prediction	4	32	82	0,71	High
Questioning	5	29	64	0,50	Medium
Hypothesis	6	76	87	0,50	Medium
Planning	7	52	92	0,77	High
Using	8	50	92	0,80	High
Concepting	9	66	71	0,01	Low
Communicating	10	48	83	0,67	Medium
Average		53	84	0,57	Medium

Based on Table 4 regarding the recapitulation of the N-Gain score from the pretest and posttest results, it was found that there was a difference in the increase of each SPS indicator. Criteria for the results from N-Gain can be seen in Table 3 in the methodology section. On the indicator, they are applying the concept of obtaining the lowest N-Gain score of 0,01 in the low category. While the highest N-Gain score was 0,8 on the indicator using tools and materials in the high category. The average result of the recapitulation gets a score of 0,57 in the medium category. Students can use tools and materials properly when carrying out simple experiments. The students are not yet able to apply the concept (Ulfa et al., 2022).

The Test of Research Hypothesis Modul Guided Inquiry Integrated Augmented Reality (M-GIIAR)

Test the research hypothesis using the prerequisite test, namely the normality test. Table 5 explains the results of the normality test using the Kolmogorov Smirnov. On the normality test results, pretest data with D_{count} results obtained a score of 0.396 with a D_{table} of 0.242. This means that the pretest data is not normally distributed because the results obtained D_{count} more than D_{table}. As for the post-test results, it was obtained that the D_{count} was 0.209, so the data was normally distributed under the D_{table}. The accumulated results of the normality test show that because there are data that are not normally distributed, it can be said that the two data are not normally distributed.

Table 5
Normality Test with Kolmogorov Smirnov

Criteria	*Pretest*	*Posttest*
Number of students	30	30
Value	53	84
$\boldsymbol{D_{count}}$	0,396	0,209
$\boldsymbol{D_{table}}$	0,242	0,242
Information	$D_{count} \geq D_{table}$	$D_{count} \leq D_{table}$
Interpretation	The data is not normally distributed	Normally distributed data

If the data obtained is not normally distributed, a nonparametric statistical hypothesis test is needed. In this study, the nonparametric hypothesis test used the Wilcoxon sign rank test. The hypothesis test was selected based on the number of students and the level of normality test results. The results of the Wilcoxon sign rank hypothesis test are presented in Table 6.

On the results of hypothesis testing with the Wilcoxon sign rank test to get the results of accepting the alternative hypothesis (Ha). This hypothesis test was chosen because, in the two pre-tests and post-test data, only one of the data was normally distributed. In a sample of 30 students, there was a significance value of 0.000 and a degree of freedom of 0.05 or 5%. So, the significant (2-tailed) results conclude that Ha is accepted in research with the hypothesis that there is a significant change in improving science process skills. The same is true of Ndoa et al. (2022), who found a change in the results before and after learning. Also in research (Jefferson et al., 1997).

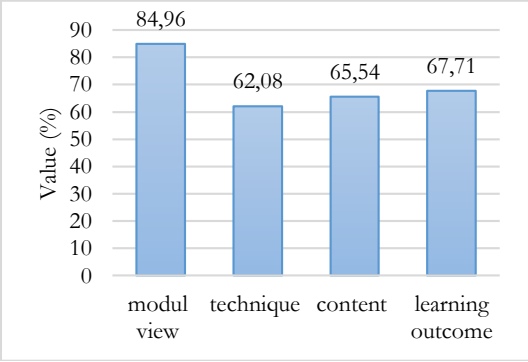
Table 6
Hypothesis Test with Wilcoxon Sign Rank

Criteria	Value
Number of samples	30
Sig. (2-tailed)	0.000
Result	Sig.(2-tailed) < 0,05
Interpretation	H_a accepted, H_0 rejected
Information	A significant difference exists between the pretest and posttest regarding students' SPS.

Student Responses to Learning with M-GIIAR

A closed interview questionnaire can collect student responses to the learning process using M-GIIAR. The results of the student response questionnaire are presented in Figure 2.

Figure 2
Students' Questionnaire Responses



Student responses are carried out to determine the results of the learning process that students directly feel. In Figure 4, you can see the rising and falling graphs, with the lowest value of 62.08% on the technical aspects of implementation. The highest value is 84.96% in the aspect of the module display. The average assessment of student responses to the guided inquiry integrated augmented reality module to improve SPS in mechanical wave material was 70.07% in the good category, meaning that students can learn well using M-GIIAR. Students feel enthusiastic about learning with AR technology because they have never known about it and are interested in learning physics with AR technology. The colorful appearance of the module adds motivation to study, and the complete mechanical wave material makes it easier to understand the material being taught. This is in line with the research of Furqan et al. (2016), which found positive responses from students towards learning.

Conclusions

This research is based on the ADDIE model, with the validity test results from media experts and material experts, which obtained very decent results with an average value of 83%. As for the implementation of the three meetings, the results obtained from the increase in graphs from the first to the third meeting is 85,58% with good effectiveness. The implementation of M-GIIAR with guided inquiry learning stages using the AABTLT with SAS assessment instrument increased at each meeting. Students with a sample of 30 students at SMAN 1 Wanayasa in class XI MIPA 4 can be followed well. Meanwhile, based on SPS indicators with ten description questions, the pre-test and post-test N-Gain results obtained an average N-Gain result of 0.57 with medium interpretation. The data from the hypothesis testing results are not normally distributed in the pre-test and post-test results. After going through the prerequisite test with the results not normally distributed. So, the researcher used a nonparametric hypothesis test with the Wilcoxon sign rank type. The result of the hypothesis test is to obtain acceptance of the alternative hypothesis (Ha), meaning that there is an increase in changes experienced by students in SPS in mechanical wave material. Students' responses after learning based on several aspects, starting from exposure to learning outcomes, obtained an average of 70.07% in the good category. So, students' science process skills need to be improved. Learning media greatly influences learning achievement; M-GIIAR can increase science process skills in mechanical wave material but does not increase significantly from the ten SPS indicators. These results are seen from the N-Gain score and learning module evaluation analysis.

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