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Learning digitalization: pocket book integrated augmented reality with differentiation approach as scientific investigation media

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Abstract

Scientific investigation activities are urgent in improving students' science process skills. So far, in science learning in higher education, there still needs to be more guidance in conducting scientific investigations, so guidance is needed to overcome this problem. This study aims to develop a scientific investigation guide with integrated innovation of 3D Augmented Reality technology using the type of research and development (R&D) ADDIE model, starting from Analysis, Design, Develop, Implementation, and Evaluation. The results obtained by the developed product are said to be feasible after going through an expert validation test with an average validity level of 94% and can also improve students' science process skills after the implementation stage, as evidenced by the results of the paired sample t-test with a significance result of 0.002 and also received a positive response from students. This shows that learning media involving Augmented Reality technology can provide students with a more interactive and exciting learning experience. Therefore, students who conduct research on the development of Pocket Books must be equipped with skills in combining online media in the form of Augmented Reality and offline media in the form of Pocket Books and follow each step of the R&D ADDIE research sequentially in order to produce valid products that can be used effectively.

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Introduction

In today's digital era, education must continue adapting to student preferences. Students tend to be more responsive to digital technology learning, such as online learning platforms, online discussions, and other digital learning resources. Thus, a learning approach integrating technology will attract students and help them understand the material better. With various technological advances that continue to develop, students are also expected to be able to adapt to the needs of the courses they take so that learning can run more effectively and efficiently.

According to Hapsari, the correct use of learning media in education is necessary to support the effective and efficient delivery of learning material (Hapsari & Zulherman, 2021). An educator must adapt to today's digital era, as Ali bin Abi Talib said, "Teach your children according to the era" (Apriyani, 2023). The same thing was conveyed that after analyzing the needs of student teaching materials, it was found that more than 50% of students needed

teaching materials to support classroom learning (Magdalena et al., 2021). In addition, it also stated that in the 21st century, the need for teaching materials is very important to meet the characteristics of the millennial generation who want to be practical and easy things, in this case learning in class needs to be supported by the help of teaching materials (Magdalena et al., 2020)

In addition to teaching materials that still seem conventional, there are still many facts that lecturers often use power points in presenting materials, so students seem not to be actively involved in learning. This can be contrary to the concept of independent learning which should involve students actively in class. In addition, the concept of independent learning also integrates with differentiated learning where the teaching and learning strategy where children can learn according to their abilities, what they like, and how they learn can be determined by themselves, so this condition is very appropriate with the current era where students prefer digital-based learning and adjust to their courses (Rohendi, 2022; Siregar et al., 2020)

Students tend to feel bored on average when learning takes place with conventional media. When examining knowledge and demanding student participation, the paradigm centered on lecturers is considered less effective, especially in the current independent curriculum; learning must be centered on students and applying a differentiated learning approach. Differentiated learning accommodates various types of students' abilities or talents in one class. In one class, there are various student abilities (Listiani, 2022a). According to the Ministry of Education and Culture, with a differentiated approach applied in classroom learning based on theory, each student has the right to develop a growth mindset (Yudha & Astuti, 2024a). Differentiated learning has the perspective that students have different understandings and readiness to learn even in one class (Atikah et al., 2023). The study's results show the success of how differentiated learning is applied to students by using the flexibility of choosing a learning model, and what is used is project-based and produces four indicators (Reffiane et al., 2024a). The first indicator is the ability of lecturers to modify materials, assignments, and projects, use technology, and continuous feedback. This is in line with the study's results that implementing differentiated learning in history and philosophy of science courses can improve understanding of concepts through challenging and relevant project and technology assignments adjusted to each student's capacity (EKAPTI et al., 2024).

During the basic science and scientific investigation lectures conducted by researchers, they only used handouts as sheets of material according to the lecture meetings assisted by the lecturer's PowerPoint materials. During the two years of teaching, it was felt that there had been no significant increase in the value of learning outcomes or skills in this course, so there was a desire to develop innovations from previous teaching materials, namely developing an AR-integrated pocketbook in basic science and scientific investigation courses with a differentiated learning approach. Basic science and scientific investigation courses are closely related to experiments and science process skills, and there are problems as centers that will be solved through investigation (Hartati et al., 2022). The scientific investigation itself has almost the exact definition of a process skill in which various types of scientific skills range from basic to advanced (Darmaji et al., 2018).

How important is scientific investigation and how to guide it? This must be supported by teaching materials or guides that can later guide students in investigating science material,

especially material at junior high school level because, by the profile of graduates of the Science Education Study Program, they will later be prepared to become science educators at the Junior High School level. Therefore, teaching materials in the form of scientific investigation guides that can train and improve the process skills of Tadris IPA students who teach basic science and scientific investigation courses here will be developed. In this development research, an innovation, a guidebook, was developed as a pocketbook; unlike guidebooks in general, digitalization was included in the form of additional Augmented Reality (AR) features. The AR integrated in it will later be in the form of a barcode scan which can later display three-dimensional images or conditions that can simulate the material (Maulana et al., 2019). In addition, integrating AR into scientific investigation activities will increase the enthusiasm and motivation of students because there is a sense of curiosity to scan the barcode until later; students can also explore how to create and implement AR in science learning (Vari, 2022). AR in learning is widespread, but it still needs to be implemented if combined with scientific investigation activities.

Thus, the objectives of this development research include analyzing and describing the feasibility of the basic science Pocket Book integrated with Augmented Reality and the results of science process skills from scientific investigation activities and student responses after using the basic science Pocket Book integrated with Augmented Reality in basic science and scientific investigation courses with a differentiated learning approach.

Method

The type of research used is development research or Research and Development (R&D). Research and Development (R&D) is a process or steps to develop a new product or improve an existing product. According to Borg and Gall (1989), educational research and development is a process used to develop and validate educational products, meaning that research and development is a process used to develop and validate educational products (Borg and Gall, 1984, n.d.; Okpatrioka, 2023; Torang Siregar, 2023) This development research was conducted to produce a product, namely an integrated augmented reality pocketbook media. The product developed is a print-based integrated augmented reality pocketbook. The development model chosen is the ADDIE model, which has five stages of development: analysis, design, development, implementation, and evaluation (Soesilo & Munthe, 2020). The population in this study were 3rd-semester students majoring in Science Education at IAIN Ponorogo in the 2023/2024 academic year, with 76 students divided into 3 classes. The sample used to determine students' conceptual understanding was class IPA.B as the experimental class and class IPA. A is the control class. Sample selection was carried out by purposive sampling.

Data collection techniques used in this study included expert validation, science process skills tests, and student response questionnaires after implementing the developed product. The developed product requires an assessment by an expert validator before being tested in the field. Validation aims to collect data and information from validators or experts in their fields to determine the feasibility of the product being developed. The validation results in the form of assessments, criticisms, and input from expert validators are used as a reference in improving and developing the product (Asri & Dwiningsih, 2022). The validators used in this study were 5 people with two lecturers and three teachers in junior high schools. By involving expert

validators, the product can be assessed from different perspectives, thus ensuring the suitability and usefulness of the product according to the knowledge and experience of each validator.

The data analysis used was a validation test with a percentage of scores based on the assessment scale provided, a hypothesis test related to differences in science process skills tests using parametric statistics t-test paired samples if the data was normally distributed, and a descriptive analysis of the results of student responses after using the developed product. (Sugiyono, 2013) provides details used as a reference for assessment in validity testing. With these guidelines, researchers can conduct a more structured and objective evaluation of the validation results. The following are the details used as a reference for assessment.

Table 1. Likert Scale Category

Information	Score
Very Good	5
Good	4
Quite Good	3
Not Good	2
Very Bad	1

(Sugiyono, 2013)

The formula used to calculate validity in percentage form is as follows:

$$P = \frac{\varepsilon x}{\varepsilon y} x100\%$$

Description:

P = validity value in percentage

εx = total score

εy = maximum score

The calculation results obtained are then described in categories according to the following description.

Table 2. Scoring Guidelines Interval Category

No	Score	Eligibility Criteria
1	81% - 100%	5
2	61% - 80%	4
3	41% - 60%	3
4	21% - 40%	2
5	0% - 20%	1

(Sugiyono, 2013)

For the questionnaire assessment, based on the results of the survey conducted, namely from the results of filling out the student questionnaire, it can be seen to what extent the attractiveness and suitability of the product that has been developed. Review of the survey results is carried out using the following formula:

(%) = (number of responses)/(maximum amount) x 100 %

The normality test is one of the methods used to evaluate whether the distribution of data samples follows a normal distribution pattern or not. Normality testing uses SPSS with the Kolmogorov-Smirnov formula and uses a significance level of 0.05. If the normality test results show a significance value (Sig.) greater than 0.05, then we can conclude that the data is normally distributed. However, if the significance value (Sig.) obtained from the normality test is smaller than 0.05, this indicates that the data is not normally distributed.
In addition, a Paired sample t-test was conducted to test the difference between two paired samples. Paired samples are the same subject but subjected to different treatments. To assess the effectiveness of the treatment, those is a difference in the average before and after treatment. The test was conducted using a significant 0.05 ($\alpha = 5\%$) between the independent variable and dependent variable. The basis for deciding to accept or reject Ho in this test is as follows. 1. If the significant value > 0.05 then Ho is accepted or Ha is rejected (the difference in performance is not significant). 2. If the significant value <0.05 then Ho is rejected or Ha is accepted (the difference in performance is significant).

Results and Discussion

The development research results will be detailed according to the sequence of stages of the ADDIE development model design, starting with Analysis, Design, Develop, Implementation, and Evaluation. First is the Analysis stage, Problem analysis, which includes related learning materials in basic science and scientific investigation lecture classes that still seem conventional. For example, teaching methods that only rely on lecturer power points without active interaction between lecturers and students. This can hinder the learning process that is effective and interesting for students. In addition, scientific investigation activities also seem conventional, where students are only given handout sheets as a guide without any direct experience in conducting research. Furthermore, the needs analysis in this development research is carried out by observing the lecture process of the course in question and then identifying things that are still lacking and can be optimized during the learning process. In addition, because the goal is to apply a differentiation learning approach later, educators must know the initial conditions of students, student learning readiness, and what students are interested in learning activities so that what is learned later can be easily understood, also by the development stages of each student. Then, the analysis of the material carried out obtained several materials or topics that will be presented in the research product for the development of a pocketbook of integrated scientific investigation guides Augmented Reality with the application of a differentiation learning approach by the Independent Curriculum Science Phase D, namely: Cells, Systems in the human body such as the human excretory system, sensory organs, ecosystems, global warming and so on.

Design is the second stage; the integrated scientific investigation guidebook Augmented Reality, with a differentiation learning approach, will be designed based on problem analysis, material analysis, and needs analysis carried out in the previous stage. Researchers identify various elements needed in a pocketbook at this stage using appropriate technology. In addition, researchers also analyze and observe various references as material for the development stage. After this process, researchers begin to compile the initial draft of the scientific investigation guidebook from the cover and the book's content plan. Namely, there are components of

uniqueness based on the independent curriculum, scientific investigation innovations, simple practicums, and Augmented Reality.

The third is Develop; this stage is a stage in developing a pocket book of scientific investigation guides integrated with Augmented Reality with the application of a differentiation learning approach according to the design that has been made. The results of product development are as in the following picture.

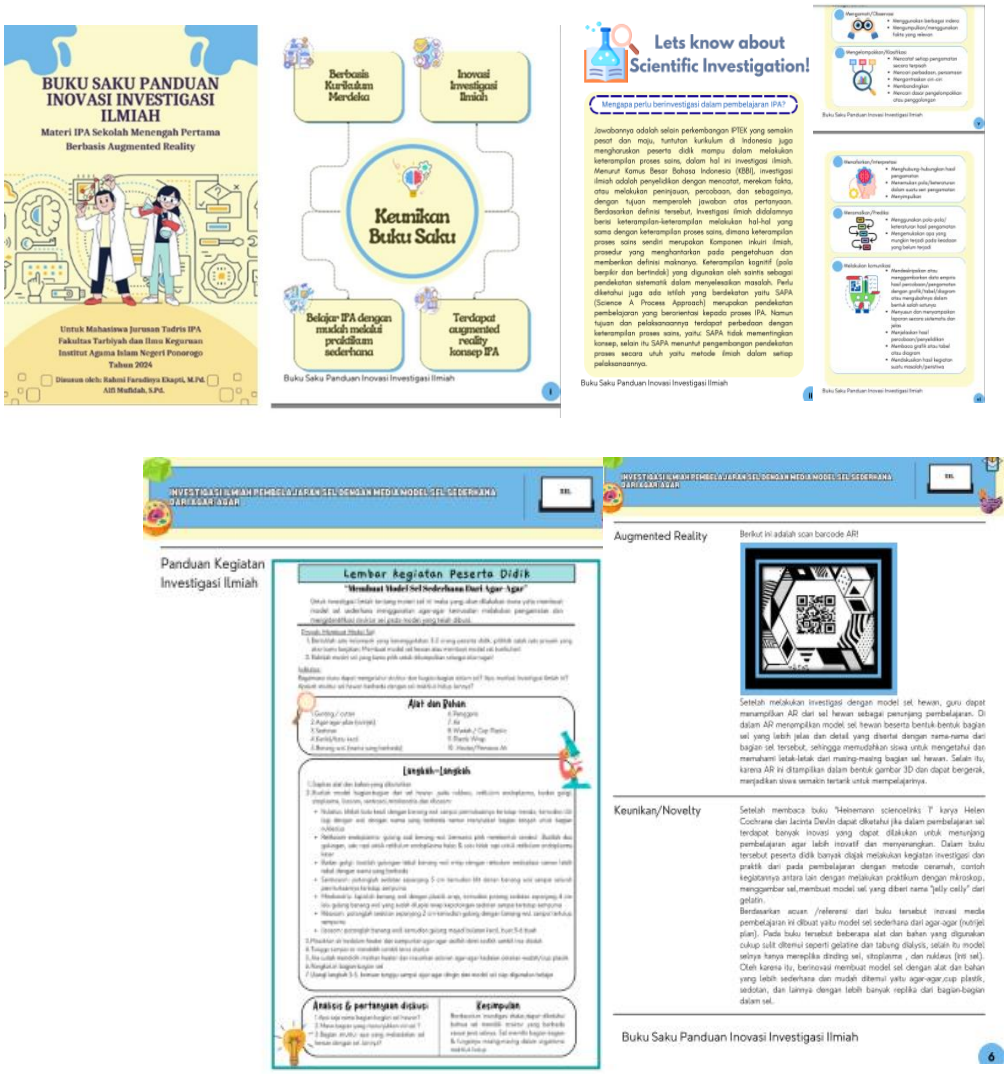

Figure 1. The Results of Product Development

The product of the learning material developed is print-based. There is digitalization in it using the Assembler Edu application, which has been given input by the validator which can be accessed in the following drive link: https://drive.google.com/file/d/1CjqEP5O74-Sb2Doz0nLtmjMu6OUpMedv/view?usp=drive_link , while an example of a AR 3D display is one of the topics in the scientific investigation guide pocket book, namely the topic "How can we see?" as in the following drive link: https://drive.google.com/file/d/1oNbzTZTuNUx3zlGy-sRR1hboRMR1ojQN/view?usp=drive_link . After being developed, the next stage is to be validated by five expert validators who have expertise in their respective fields in accordance with the products to be validated, namely material experts, educational technology experts, and

learning media experts. 3 experts from lecturers while 2 experts from teachers who already have a lot of experience in the field, of course. Based on the instrument that has been created; in this case, 5 expert validators are used to assess and provide input related to the scientific investigation guide pocketbook integrated with Augmented Reality with the application of the differentiation learning approach that has been developed. The following presents the average percentage of the validation results from the 5 validators above.

Table 3. Product development results

No	Assessment aspects	Validity Level	Presentation
1	Language suitability	Valid	0.93
2	Content suitability	Valid	0.95
3	Presentation suitability	Valid	0.93
		Average amount	0.94

Based on the data in Table 1 above, the percentage of expert validation, it is known that the average expert validation results for the three assessment aspects above are 0.94, calculated using the scale listed in Chapter III above. Based on the results obtained, the average value of 0.94 can be said to have a valid category. The three validators gave an average value of 0.93 for the aspect of language feasibility according to BSNP and for the aspect of material content feasibility, namely 0.90. Finally, for the aspect of presentation feasibility, it is 0.94.

Next, the result of implementation stage, namely implementing the book that has been developed and, after that, testing how the student's science process skills test. The research approach was quantitative with experiment methode and using posttest-only control group design (Anggraeni et al., 2019) There were two classes of science education departement of IAIN Ponorogo, that was experiment class (given pocket book) and control class (discussion and lecturing only). After implementing the developed product, so they given test about science process skills. The documentation of the experiment class as follow.

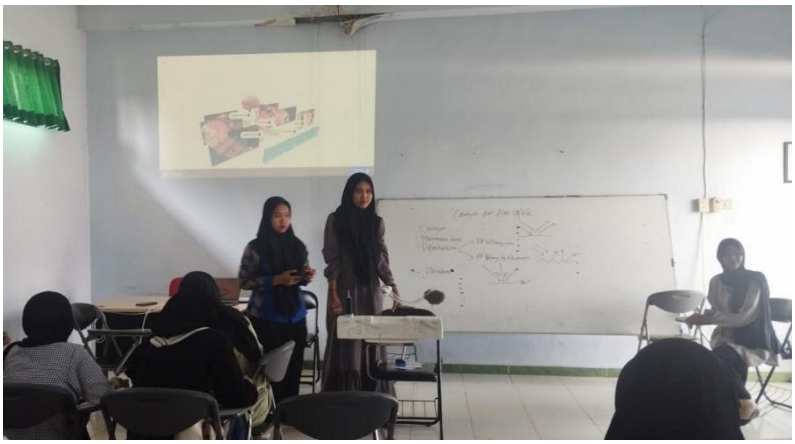

Figure 2. An experimental Class with Augmented Reality

Figure 3. An Experimental Class of Product Implementation was Developed

After getting data, the next test stage can use parametric statistical tests because the normality data was normal and homogent. And the test that will be carried out is a hypothesis test using a paired sample t-test to find out whether or not there is a difference in the increase in the experimental class and the control class. The hypothesis is H0: There is no difference in the average results of students' science process skills tests after using the Augmented Reality integrated scientific investigation guide pocketbook. And H1: There is a difference in the average results of students' science process skills tests after using the Augmented Reality integrated scientific investigation guide pocketbook

The paired t-test was conducted involving the control and experimental classes. The method used in the t-test was conducted by involving post-test data in the experimental and control classes. The results were obtained as in the following table based on the paired sample t-test conducted using SPSS 27.

Table 4. T-test results

Paired Samples Test								
		Paired Differences				t	df	Sig (2-tailed)
		Mean	Std. Deviation	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1	Class A posttest - Class B posttest	-6,136	7,942	1,693	-9,658	-3,624	21	,002

The test results using SPSS 27 above obtained a significance of 0.002 <0.05. It can be seen that Ho is rejected, which means there is a difference in the average results of students' science process skills tests after using the Augmented Reality integrated scientific investigation guidebook. From the results of the analysis, the use of the Augmented Reality integrated scientific investigation guide book has a significant impact on improving students' science process skills. This shows that Augmented Reality technology can provide students a more interactive and exciting learning experience.

The last stage is Evaluation; in this stage, students are given a response questionnaire to see how the Evaluation after learning activities using the scientific investigation guidebook

integrated with Augmented Reality through a survey using Google Forms. Based on the data obtained, the average student response to the product practicality instrument scores above 50%, included in the outstanding assessment category. This indicates that the student response is very positive towards the learning media used, namely animation-based videos. With this excellent response, the learning media is efficient and effective in the learning process. The practicality questionnaire given to students also covers several important aspects, such as interest, content, language, and presentation methods. This shows that the practicality evaluation is carried out comprehensively to ensure the effectiveness of the learning media.

This research is the development of a guidebook for Augmented Reality integrated scientific investigation activities where there are several interesting features or components, which are features that will help students and later for students in practicing science process skills. The development of this Augmented Reality integrated scientific investigation activity guidebook uses the ADDIE model design, namely Analysis, Design, Develop, Implementation, and Evaluation. The researcher has carried out five stages of ADDIE in order and runs smoothly until the product is produced properly with a lot of help from parties. In accordance with the theory, one of the advantages of the ADDIE model is that researchers can set schedules in a structured manner and can also provide a structured approach in learning design (Nursaida et al., 2020).The product design included in the scientific investigation activity guidebook integrated with Augmented Reality is by the curriculum used, namely the independent curriculum where in this curriculum in learning outcomes there must be elements of both science understanding and elements of science process skills in the subject of Science Phase D., in this case, prospective students are also required to understand and master the learning outcomes in the curriculum (Ramadina, 2021).

ADDIE has been carried out in order starting from the stage of problem analysis, needs analysis and material analysis to continue with the design stage. The product design included in the Augmented Reality integrated scientific investigation activity guidebook is in accordance with the curriculum used, namely the independent curriculum where in this curriculum in learning outcomes there must be elements of both science understanding and science process skills elements in science phase D subjects (Ramadina, 2021)

In addition, because the goal is to apply a differentiated learning approach, educators must know the initial condition of students, student learning readiness, and what students are interested in in learning activities so that they can learned later can be easily understood, according to the stages of development of each student. Therefore, before learning starts, lecturers provide several surveys or initial diagnostic tests before learning starts through google forms related to the use of technology in learning. For example, in the independent curriculum, one of the learning objectives is for students to be able to apply science concepts creatively in designing innovative products (Listiani, 2022). This can be reflected in the product design produced through scientific investigation activities contained in the scientific investigation guide pocket book using Augmented Reality technology. Thus, students not only understand science theories, but are also able to implement them in a real context.

A concrete example of this can be seen in scientific investigation activities using Augmented Reality technology. Through the pocket book of scientific investigation guides, students not only understand science theories, but can also implement them in real situations.

Thus, they not only learn theoretically, but also practically. In addition, the differentiated learning approach also allows students to develop skills that are relevant to the real world, so that they are prepared for future challenges. By understanding the needs and interests of students, learning can become more effective and engaging for all parties involved (Yudha & Astuti, 2024).

When learning takes place with conventional media, the average student tends to feel bored. When studying knowledge and demanding student participation, the lecturer-centered paradigm is considered less effective, especially in the current independent curriculum, learning must be student-centered and with the application of a differentiated learning approach. Differentiated learning itself is used to accommodate various types of abilities or talents of students' interests in one class. We believe that in one class there are various abilities of students. (Listiani, 2022) According to the Ministry of Education and Culture, with a differentiated approach applied in classroom learning based on theory, every student has the right to develop with a growth mindset (Reffiane et al., 2024).

The indicators of technology use are in great demand by students, they are very challenged with what is the three-dimensional media of Augmented Reality. Lecturers provide several examples and simulations in the scientific investigation guidebook and then later at the end of them there is an assignment to start learning to make an Augmented Reality product and include it in the Augmented Reality column that has been provided in this pocket book. How important it is to conduct scientific investigations and how the guidelines are, it is very important that this is supported by teaching materials or guidelines that can later guide students in the investigation of science materials (Angga Putra et al., 2021). Especially materials at the junior high school level, because in accordance with the profile of graduates of the Science Study Program that they will be prepared to become science educators at the junior high school level.

Therefore, teaching materials in the form of scientific investigation guides where they can train and improve the process skills of Science students who teach basic science courses and scientific investigations here will be developed. For example, in Augmented Reality integrated scientific investigation activities, students need to make detailed observations of the object being studied, measure various relevant variables, and analyze the data obtained to conclude significant findings, but sometimes there are science concepts that cannot be simulated in real life, so they need the help of technologists like AR(Djunaedi et al., 2022).

Thus, by applying product design in the context of the Merdeka curriculum, prospective students will be skilled in combining their understanding of science concepts with science process skills (Sudibyo et al., 2018). This will equip them with the skills needed to become competent and innovative professionals in the fields of science and technology. For example, one of the interesting features that can be found in this guidebook is the application of Augmented Reality simulations that allow students to conduct virtual experiments in a controlled environment. This can improve their understanding of scientific concepts that are difficult to understand through conventional learning. By using the ADDIE model design, the development of this guidebook ensures that every step, from analysis, design, development, and implementation to evaluation of the integrated scientific content of Augmented Reality is well structured (Cahyadi, 2019).

In the context of the curriculum used, this guidebook aligns scientific investigation materials with applicable curriculum standards, thus providing relevant and supportive guidance for students and learners. Thus, book users can develop their science process skills more comprehensively and in a directed manner. Overall, using Augmented Reality in this scientific investigation guidebook provides an innovative learning experience and enriches traditional learning methods.

The difference with other products is that this scientific investigation guide pocket book offers features that can increase students' interest in learning because it has various supporting features, especially the use of technology integration in it, which so far is usually only books that are not integrated with Augmented Reality, and also the features offered can stimulate students' ability to argue and increase their understanding of concepts, which is the goal of learning and especially this research.

Conclusion

Based on the research that has been conducted, data was obtained showing that this Augmented Reality integrated scientific investigation guidebook is suitable and valid for use, with an average validity level of 94%. Improvement efforts have been implemented to increase the effectiveness and validity of the developed product. Although several areas need to be improved, this Augmented Reality integrated scientific investigation guidebook still meets the requirements. In addition, the Augmented Reality integrated scientific investigation guidebook effectively improves students' science process skills related to basic science and scientific investigation courses, which show significant improvements.

The results of the paired sample t-test obtained a significance of 0.002, which is <0.05, which means that there is a difference in the average results of students' science process skills after using the Augmented Reality integrated scientific investigation guidebook. From the results of this analysis, using the Augmented Reality integrated scientific investigation guidebook significantly impacts students' science process skills. This shows that learning media involving Augmented Reality technology can provide students with a more interactive and exciting learning experience.

The limitations of this study was conducted on a specific group of students, which may limit the generalizability of the findings. Future research could expand the scope by involving students from various educational levels and backgrounds.The implementation of Augmented Reality (AR) requires adequate devices and infrastructure. Some students may face technical difficulties in accessing or using AR features, which could affect learning effectiveness.This study evaluates the effectiveness of the Pocket Book integrated with AR over a limited period. Further research is needed to examine its long-term impact on students' conceptual understanding and scientific investigation skills. Future research is needed a comparative study between Pocket Book AR-based learning and other digital learning methods, such as interactive e-learning or virtual reality, could provide broader insights into its effectiveness. By addressing these limitations and exploring future research opportunities, the digitalization of learning using AR-integrated Pocket Books with a differentiation approach can be further refined and effectively applied in various educational contexts.

Credit Authorship Contribution Statement

Rahmi Faradisya Ekapti: Conceptualization, Methodology, Writing-original draft, Writing-review & editing, Project administration. **Alfi Mufidah**: Software, Visualization, Formal Analysis, Writing-review & editing.

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