Augmented Reality with A Cognitive Conflict Model and STEM Integration on Newton's Universal Law of Gravitation: Does Practicing Practical Learning Support Scientific Literacy?

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***Abstract*—The presence of technology supports innovative learning in overcoming limited learning problems in discussing abstract material objects. AR is one of the technologies that supports simulation in explaining complex and abstract scientific phenomena. This research aims to design AR with a cognitive conflict model that integrates Science, Technology, Engineering, and Mathematics (STEM) into Newton's universal law of gravitation. The method used in this research was the stages of the Plomp model design. The research stage includes the design product, self-evaluation, validity, practicality, and effectiveness tests. Data in the research were obtained using validity instruments, practicality instruments, and scientific literacy tests. The product was designed as an AR application in APK format that could be installed on smartphones, containing material on Newton's universal law of gravitation using a cognitive conflict model approach integrated with STEM concepts. The average validity test result was 0.945, categorized as valid. In the practicality test, one-to-one and small-group evaluations yielded scores of 99.58 and 91.44, categorized as very practical. The effectiveness test results showed a %N-gain improvement in learning outcomes of 59%, categorized as moderate. The results of the paired sample t-test revealed that AR significantly impacted the improvement of students' scientific literacy abilities. With a cognitive conflict model integrating STEM into Newton's universal law of gravitation, AR has been validated as valid, practical, and effective. Thus, the developed product has supported practical and effective learning in improve students' scientific literacy abilities related to Newton's universal law of gravitation. In further research, other researchers are encouraged to assess effectiveness by incorporating variables related to 21st-century skills and high-level technologies, such as virtual reality and the metaverse.**

***Keywords*—augmented reality, cognitive conflict, scientific literacy, Science, Technology, Engineering, and Mathematics (STEM)**

I. INTRODUCTION

Technological advances have significantly reformed the order of life. Technology encourages efficiency in obtaining information and communicating. This transition is marked by the era of Society 5.0, where technology is directly involved in all human activities, making it easier to present information and communication in an increasingly real reality [1, 2]. Technology is now developing not only in two-dimensional views but also involves three-dimensionality in the dissemination of information [3].

Augmented Reality (AR) is a form of technology that supports delivering information not only in a three-dimensional view. This technology combines virtual objects with real-world environments [4]. Digital technology, such as smartphones and computers equipped with cameras, is a form of implementation of this technology that supports the presentation of information in a simpler and easier-to-understand manner [5]. This condition has caused AR to become a trend and popular in various fields, including education [2]. Replication of objects displayed through AR close to real objects, supporting simulation in learning [6].

Physics is one of the fields of learning that requires simulations to present and study phenomena. In discussing physics, natural phenomena and everyday events are important objects of study in solving problems arising from these phenomena. Not all objects and phenomena in physics can be presented directly and observed, so simulation media is needed to replicate these phenomena with an approach close to real objects [3]. One of the physics studies that is difficult to do in a limited scope is the study of Newton's law of universal gravitation, which is related to the interaction of forces between planets and celestial bodies. Simulation is an alternative media that supports the study.

There are several issues in school regarding explaining Newton's law of universal gravitation. In previous teaching methods, the material was presented in a limited way. The teacher still uses one-way conventional methods, and there isn't specific experimental media to support learning about Newton's law of universal gravitation. The teaching material mainly relies on two-dimensional images and videos [7–9]. This condition is a problem in supporting students' ability to participate in the scientific investigation process, which is part of students' scientific literacy. In addition, the results of previous research revealed that students' scientific literacy in the study of the material was relatively low [10, 11]. This is supported by the results of the Programme for International Student Assessment (PISA), which shows that the scientific literacy scores of Indonesian students are in the low category [12]. This condition is a problem because materials related to technology and celestial bodies are part of the content of student scientific literacy in international standards.

Scientific literacy is related to the ability to explain, interpret, and investigate phenomena [12]. Physical materials, such as Newton's law of universal gravitation, are part of the context of scientific literacy. The presentation of phenomena is an important part of supporting the mastery of these skills. AR, a new technology not offered by previous technologies limited to two-dimensional displays, combines three-dimensional objects with the real world. This presence aligns with the characteristics of physics learning and supports scientific literacy.

A review of learning studies involving the scope of Science, Technology, Engineering, and Mathematics (STEM) is required to acquire complete and broad knowledge. These four elements support investigation, explanation, and interpretation in scientific literacy. The learning approach in this review is oriented towards STEM approaches. One of the materials that can be adopted through the STEM approach is the discussion of Newton's universal law of gravitation. In a scientific approach, this material is related to celestial phenomena such as planets, stars, and satellites that are affected by the effects of gravitation. AR technology is one of the approaches used in discussing the material, such as displaying rocket phenomena that can escape the influence of gravitational forces. As a form of innovation in learning, the engineering approach in the STEM context focuses more on the design and simulation process in a virtual environment. Through AR technology, students can understand engineering principles by studying components and designing rockets virtually, which is a practical representation of the application of science and mathematics. In the mathematical approach, its role is very important to determine the formulation and calculation of data processing activities of the investigation process.

The cognitive conflict model is one of the learning models that supports the process of investigation, data collection, and observation of phenomena. The distinctive feature of this model is its ability to support learning through experiments, adopt technology in learning, and correct misconceptions. Technology is an important pillar in supporting learning, and this model is used to orient the investigation process. Therefore, AR is well suited to be adopted as a technology implemented in this model of cognitive conflict, as it can present interactive visualizations that support deeper investigation and understanding of concepts.

In this study, learning innovation through AR technology aims to improve the understanding of Newton's universal law of gravitation concept by emphasizing a cognitive conflict model-based design. Based on the findings of previous research, cognitive conflict-based models have been proven to be effective in improving students' understanding of complex concepts [13–15]. Previous researchers have also found that integrating technology into learning can create a more dynamic learning environment and support scientific literacy [16, 17]. AR technology is adopted in learning to support visualization, simulation, and experiments on Newton's universal law of gravitation material to improve students' scientific literacy. This is because teaching previously had limitations in supporting media and educational equipment in training scientific literacy in the country [11]. The findings form the basis for developing this AR-based app, where STEM approaches and cognitive conflict models are brought together to create richer and more interactive learning experiences.

The combination of the advantages of AR technology, review in learning through STEM, and systematic preparation of learning with cognitive conflict models is a complete combination to support scientific literacy learning, especially in improving the understanding of concepts in Newton's law of universal gravitation. The latest innovations in supporting learning as a whole involve AR technology, STEM approaches, and cognitive conflict models that have overall characteristics aligned with supporting scientific literacy in Newton's law of universal gravitation. This research aims to design a cognitive conflict-based AR application integrated with STEM. The purpose of this study is to answer the following research questions:

1) What is the form of AR design with a cognitive conflict model that integrates STEM to improve students' scientific literacy related to Newton's universal law of gravitation?
2) What are the results of the validity test of AR with a cognitive conflict model that integrates STEM to improve students' scientific literacy related to Newton's universal law of gravitation?
3) What are the results of the practical test of AR with a cognitive conflict model that integrates STEM to improve students' scientific literacy related to Newton's universal law of gravitation?
4) What are the results of the effectiveness test of AR with a cognitive conflict model that integrates STEM to improve students' scientific literacy related to Newton's universal law of gravitation?

II. Literature Review

A. Augmented Reality (AR)

AR is a popular technology in this decade in the educational environment. This technology has advantages in object visualization compared to previous technologies. In previous technology, information was presented in digital form as a two-dimensional display. The presence of AR technology provides a presentation of digital information in a three-dimensional form that can be close to real conditions [4]. The visualization of AR technology that realizes real objects in a virtual environment drives this technology to help provide simple and complex explanations in learning [18]. This technology has been applied in various fields of science and can encourage students' interest and motivation to learn [19].

In physics learning, phenomena are the most important part of uncovering the facts of the cause of an event. The popularity of visualization in learning was developed in digital form by previous researchers and is dominated by images and videos. The form of media development and teaching materials is limited to e-books and flipbooks, which make the image and video information presenting information [7]. AR presents more complex and simple interactivity in its use. Visualizations in a three-dimensional view in AR can be zoomed in, zoomed out, and rotated [20, 21]. In addition, more complex media visualization in AR can present a virtual laboratory that supports experiments and data collection in physics learning.

Not all phenomena can be visualized in physics, such as Newton's law of universal gravitation on planets whose observations relate to celestial bodies. Images and videos have limitations in presenting this information in a form close to reality. AR, as an innovative technology, can present this phenomenon in a real environment in virtual form. AR objects like the original support the explanation of physical phenomena to be closer to their original conditions in explaining the phenomenon to encourage better mastery of concepts for students.

B. Cognitive Conflict Models

The cognitive conflict-based learning model is oriented to support students' understanding of concepts in learning. This model has several stages of the learning process, including activation of preconceptions and misconceptions, presentation of cognitive conflicts, discovery of concepts and equations, and reflection [22]. Each syntax aims to encourage students' mastery of concepts in the direction of scientific thinking [23].

In the preconception activation stage, the main role is to activate the student's initial ability to understand the material discussed. The stage of presenting cognitive conflict trains students to make hypotheses about the cause of a problem [22]. In-depth analysis of scientific phenomena encourages students to better explain the phenomenon. In testing the correctness of the hypothesis, the concept and equation discovery stage plays a role in training students' experimental skills [9]. Experimental activities investigate phenomena' problems by collecting and interpreting data for scientific conclusions.

The reflection stage is the last part of the cognitive conflict model. This stage encourages students to measure their learning ability after passing the previous stage [24]. Presenting information and conclusions is part of improving learning at this stage in obtaining complete knowledge through scientific steps [25]. Overall, the cognitive conflict-based learning model has the advantage of supporting students in explaining scientific phenomena in physics more directly, accompanied by scientific proof stages through experiments [26]. The characteristics of this model are scientific literacy indicators that strengthen the ability to explain, investigate, and interpret data. In addition, the support of AR technology is part of the correlation in presenting scientific phenomena, such as Newton's law of universal gravitation material, which discusses the motion of the planets in a realistic form through a virtual display. Scientific literacy is synonymous with the context of scientific phenomena, such as celestial bodies, which require visualization in their presentation. AR can provide strong support for the advantages of this technology. Thus, the cognitive conflict model, scientific literacy, and AR have compatibility in supporting the explanation of physics material well in Newton's law of universal gravitation.

C. Science, Technology, Engineering, Mathematics (STEM)

STEM is a learning approach that discusses the viewpoint of a problem in science, technology, engineering, and mathematics. Physics as a branch of science is appropriate for discussion in a STEM approach to acquire complete knowledge [27]. The integration of STEM approaches has been applied in physics learning in the context of presenting materials in science, technology, engineering, and mathematics, which is dominated by teaching materials in print and digital form [28]. Printed learning with a STEM approach generally utilizes e-books and flipbooks [29]. The information presented in digital learning has limitations in a complete review related to the presentation of the context of science, technology, and technical review.

STEM is related to the discussion of various groups of sciences. The presentation of information in physics, such as Newton's law of universal gravitation, is a specific part of the study of physical matter that requires the visualization of phenomena [30]. Technology in the form of media, such as AR, has a significant role in supporting STEM approaches. In supporting engineering design, the STEM approach requires experimental activities in investigation through the discovery stage [31]. The characteristics of the discovery are in line with the stages of the cognitive conflict model and the ability of AR to present experiments virtually. Mathematics supports data processing and encourages students to interpret information from the data obtained into a conclusion.

Overall, STEM approaches connect with AR technology to visualize phenomena and technology. In supporting systematic learning, discovery-oriented learning, such as cognitive conflict models, is aligned with STEM approaches. Studies in acquiring complete knowledge in STEM approaches have characteristics that support the mastery of scientific literacy.

D. Scientific Literacy

Scientific literacy is related to scientific content, and context is closely related to studying scientific phenomena. In context, the object of scientific literacy study includes daily life phenomena such as the environment, health, technology, and celestial bodies. In physics learning, the object of study is related to the discussion of Newton's law of universal gravitation, which relates to celestial and mass bodies. These results are in line with scientific literacy studies. In the presentation of scientific literacy, the important scientific abilities to be mastered consist of explaining, investigating, and interpreting data. This ability is the standard for obtaining good knowledge and understanding of every science material.

The real condition is that Indonesian students' scientific literacy ability is low. The results of PISA 2022 reveal that Indonesia has a score of 386, while the OECD minimum average score is 489 [12]. The test results show that students' ability to explain, interpret, and conduct scientific investigations is relatively low [11, 32]. This reveals the limitations of support media in scientific literacy learning that are not yet available comprehensively and are not optimal [33]. Information in scientific literacy is related to natural phenomena, and not all physical materials can be explained concretely in the form of real objects. As in Newton's law of universal gravitation, visualization is needed to explain it.

The availability of support for inquiry-oriented learning stages and learning approaches that support complete mastery is an important part of supporting students' scientific literacy.

The presence of visual media is an aspect that needs to be considered in supporting explanations [34]. AR is one of the best visual technologies for scientific phenomena to explain phenomena that are difficult to visualize in the real environment. The technology has good support in explaining scientific phenomena and supporting students' mastery of scientific literacy. In addition, systematic learning supports such as cognitive conflict models and STEM align with students' ability to explain scientific problems more complexly, support systematic investigation, and interpret data more systematically to reach complete conclusions. The alignment of AR characteristics, cognitive conflict models, and STEM approaches can be used to support students' mastery of scientific literacy more optimally on Newton's law of universal gravitation.

E. AR, Cognitive Conflict Models, STEM, and Scientific Literacy in previous research

AR has become an urgent research focus this decade as a learning medium. Meanwhile, STEM is recognized as a popular approach that supports students' mastery of abilities in various fields of science. In a study that supports students' cognitive abilities, one of the new models applied in learning is the cognitive conflict model. In addition, scientific literacy is an important issue because it is one of the standards used to measure students' ability to explain, investigate, and interpret data [12]. Therefore, the research focus on AR, cognitive conflict, STEM, and scientific literacy is becoming increasingly popular among researchers, resulting in various findings and limitations in its application. The results of the comparison of the focus of the previous study and its limitations are presented in Table 1.

Table 1. Previous research and its limitations

Source	Focus	Limitation
[29]	STEM and digital teaching material	STEM was presented only as content in the work steps in teaching materials
[35]	Interactive multimedia and cognitive conflict models	Limited interactivity presentation of 2D image display in the stage of the cognitive conflict model
[36]	Physics and AR	AR was presented as a limited visualization without interactivity
[37]	STEM and scientific literacy	STEM was presented as a process of communication approach in training scientific literacy
[38]	Cognitive conflict models	Focusing on the implementation of cognitive conflicts in direct learning
[9]	Cognitive conflict models and video	Video as a supporting presentation medium at the stage of the cognitive conflict model
[39]	AR and engineering	AR was limited to the presentation of phenomena visualization content about engineering mechanics.

Table 1 presents the research focus divided separately on each content. There are limitations from previous research that provide a gap for further development, such as the latest innovation in this study. In this context, STEM was presented as material content that only accommodated a small part of the teaching materials at the learning stage. The presentation of technical content with AR was limited to visualizing three-dimensional objects without interactivity with the virtual objects displayed.

Studies on the cognitive conflict model also showed that its implementation is still limited to media in videos and images used to support the learning process. The application of AR in learning generally did not include interactivity on virtual objects, so it only functions as a visualization medium without involving simulation, experimentation, and data collection activities. This shows that previous research has limitations in supporting improving scientific literacy learning.

The diversity of limitations displayed in previous studies provides a gap that needs to be complemented as an innovative solution. In supporting the presentation of media limited to images and videos, the development of interactive AR allows support for data collection, simulation, and visualization of the displayed objects. The learning process was presented systematically through the stages of the cognitive conflict model, which has advantages in improving the understanding of physics concepts.

In addition, STEM was presented systematically in the context of scientific phenomena regarding Newton's law of universal gravitation. Technologies that utilize AR and engineering were carried out in a virtual environment, especially in designing tools such as rockets, where mathematics played an important role in calculating the design. Thus, integrating AR, STEM, and cognitive conflict models has characteristics that support improving students' scientific literacy.

III. METHODS

A. Method and Design Research

This study applies research steps using the Plomp model. The design stages in the Plomp model consist of product design, self-evaluation, validity test (expert review), practicality test (one-to-one and small group), and effectiveness test [40]. This model was chosen as a stage of AR development design because it presents clear and simple stages in the educational product design process. The stages of the Plomp model adopted in this study are presented in Fig. 1.

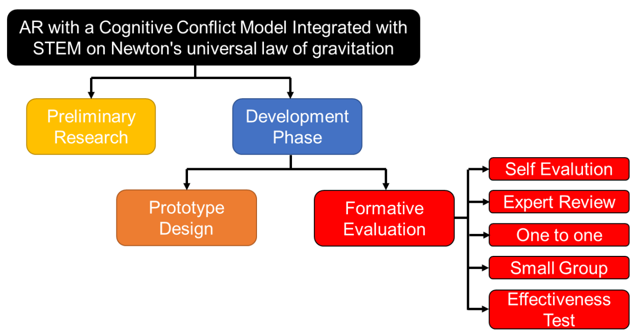


Fig. 1. Research design of the Plomp model.

Fig. 1 shows the design stage of Plomp's development in developing AR, a stage of a cognitive conflict model that integrates STEM to support scientific literacy regarding Newton's universal law of gravitation. The initial stage of the research began with a preliminary analysis as a source of data to identify research problems. The data that was used in the preliminary analysis served as a reference for designing the development of AR.

The development stage began with the creation of a product prototype. After the product was designed, testing consisted of self-evaluation, expert review, one-to-one evaluation, and small-group evaluation. Each evaluation stage aimed to produce a high-quality product based on the assessment results. The instruments used for data collection consisted of validity instruments, practicality instruments, and scientific literacy tests.

The one-shot pretest-posttest experimental design was used to test effectiveness. This stage aimed to determine the differences in student learning outcomes before and after using AR media. The pretest-posttest instruments consisted of 14 validated multiple-choice questions on scientific literacy that were designed to measure improved student learning outcomes.

B. Participant

Participants in this study were scattered throughout the preliminary research, validity test, and practicality test stages. In the preliminary research, problem data from 3 teachers was obtained through an interview process. In the validity test, six experts were involved to assess the quality of the developed product. Experts play a role in assessing the learning content and design of the technology. Three experts focus on assessing learning content in the form of material substance and learning design, and three other experts focus on using AR technology, especially related to the display and use of software. Experts involved in the validator process consist of professors and doctors. In the practicality test, 21 students were divided into three who participated in the one-to-one evaluation and 18 who participated in the small-group evaluation. The students involved in the practicality test of this product were senior high school students aged 15 to 16 years. The number of participants consisted of 15 females and 6 males. The effectiveness test was through implementation in learning, which involved 26 students. The learning process consists of 20 female students and six male students.

C. Data Collections

Data in the study were collected through interviews, validity instruments, practicality instruments, and scientific literacy tests. Data was obtained from the respondents' answers based on the assessment given on the instrument. The respondents for the validity test were experts, while the respondents for the practicality test were students. The data collected in the validity test contains information related to product quality on certain indicators. The data obtained was then processed using Aiken's equations, as follows:

$$V = \frac{(\text{Score From Expert - The Lower Score})}{(\text{Number of Category (Number of Expert - 1)})} \quad (1)$$

The value obtained was interpreted from the total result obtained from the calculation using the Aiken value. The data was interpreted based on graduation standards and validity indicators. The minimum limit of a product was declared valid if the value of V Aiken was more than 0.8. Valid products could proceed to the practicality testing stage. The results of the data obtained were processed using the percentage technique to process practical data. The following formula calculates the percentage of practicality:

$$P = \frac{\text{Score Student}}{\text{Maximum Score}} \quad (2)$$

The results of the practicality data obtained from the test were analyzed based on the passing standard to determine the category of product practicality. A product was declared practical if the percentage value of practicality was 61 to 80. The product was considered very practical if the percentage value of practicality reached 81 to 100. In general, the limit of product practicality was in the range of 61 to 100. If the score was below the range of 61, then the product was declared impractical and required further improvement.

The data during the implementation phase was obtained through effectiveness testing using the scientific literacy test instrument during the pretest and posttest stages. The data was then analyzed using SPSS version 26. The data was tested for normality using the Shapiro-Wilk test, which is appropriate for small research samples. The processed data results were analyzed through N-gain and parametric statistical tests using paired sample t-tests. To investigate the N-gain values of students' scientific literacy abilities, the interpretation of the results was based on N-gain criteria. If N-gain is < 30%, the improvement effect is considered low; 30% ≤ N-gain ≤ 70% is considered moderate improvement; and N-gain > 70% is considered high improvement. The conclusion from the paired sample t-test is drawn based on the t-value and p-value. The interpretation of the effect of AR learning on learning outcomes is based on the significance value. If p-value < 0.05 or t-value < -2.06, it is concluded that AR learning can enhance students' scientific literacy abilities.

D. Product Implementation

The product testing procedure was carried out through validity, practicality, and effectiveness testing stages. The product prototype was sent to experts, and they were asked to be willing to install the product on their respective smartphones for validity testing. In addition, the experts were given 1 to 2 weeks to test the developed product components and then fill out the validity assessment instrument provided. Practicality test through one-to-one evaluation and small-group evaluation stages. In the one-to-one and small-group evaluations, the product was directly sent to students, who were asked to install it. Each student receiving the product file was requested to install the application on their smartphone. Students were given a 40-minute to use the application in the learning process. After the specified time limit, students were asked to fill out an instrument to assess the product based on their AR application experience.

At the effectiveness stage, arrangements are made in the research process. Teachers involved in learning are given treatment to understand the use of AR-based learning. Then, in the learning process, each student is asked for his willingness to install the application. Before the instructional treatment was applied, a pretest was conducted to measure students' initial scientific literacy abilities. Subsequently, students receive treatment in the form of AR-integrated learning throughout the entire learning process. AR-based learning is conducted over three sessions, each lasting 120 minutes. After completing the AR-based learning, students' final abilities are assessed to evaluate learning outcomes related to scientific literacy following the use of AR.

IV. Result

The preliminary analysis was carried out through a needs analysis based on the results of interviews with three teachers related to problems in learning. From the interview, data was obtained about physics learning problems, especially in the sub-material of Newton's law of universal gravitation. Two main problems in physics learning in Newton's law of universal gravitation material were obtained from the interviews: (1) teachers still apply direct learning methods that focus on students, (2) the unavailability of teaching materials to support student learning in practising scientific literacy.

Learning Newton's law of universal gravitation, which was currently implemented, still focuses on one-way learning. The information and materials presented are limited to examples in the form of pictures and explanations on the board. This method was less relevant to the content of Newton's law of universal gravitation, indicating the limitations of media, teacher-centred learning approach, and lack of interactivity in physics learning in Newton's law of universal gravitation.

This problem impacts students' low scientific literacy ability, considering that this material requires presenting content based on the context of real phenomena and supporting scientific investigations that encourage students' desire to practice their scientific literacy. The results of this needs analysis align with the results of the PISA test, which revealed that the presentation of learning-oriented to the real-world context, the implementation of investigations, and the interpretation of data of Indonesian students are still low. One of the subtopics in the scientific literacy component that is assessed is Newton's law of universal gravitation.

One of the alternative solutions that can support learning in real-world, interactive, and systematic contexts to support the mastery of scientific literacy is to design innovative interactive teaching materials in the form of AR. AR allows the representation of physical phenomena according to their context, presenting interactive simulations. In addition, to support a complete and systematic learning presentation, a STEM approach and a cognitive conflict learning model that aligns with the characteristics that support the mastery of scientific literacy in Newton's law of universal gravitation material were needed.

A. What Is the Form of AR Design with a Cognitive Conflict Model That Integrates STEM to Improve Students' Scientific Literacy Related to Newton's Universal Law of Gravitation?

AR was designed based on learning problems in Newton's law of universal gravitation. The needs analysis results showed the urgency of interactive teaching materials that were presented systematically and supported the mastery of scientific literacy. Based on these problems, an interactive storyboard of teaching materials in the form of AR was designed. This AR contains content about the phenomenon of Newton's law of universal gravitation. The AR storyboard display design is presented as seen in Fig. 2.

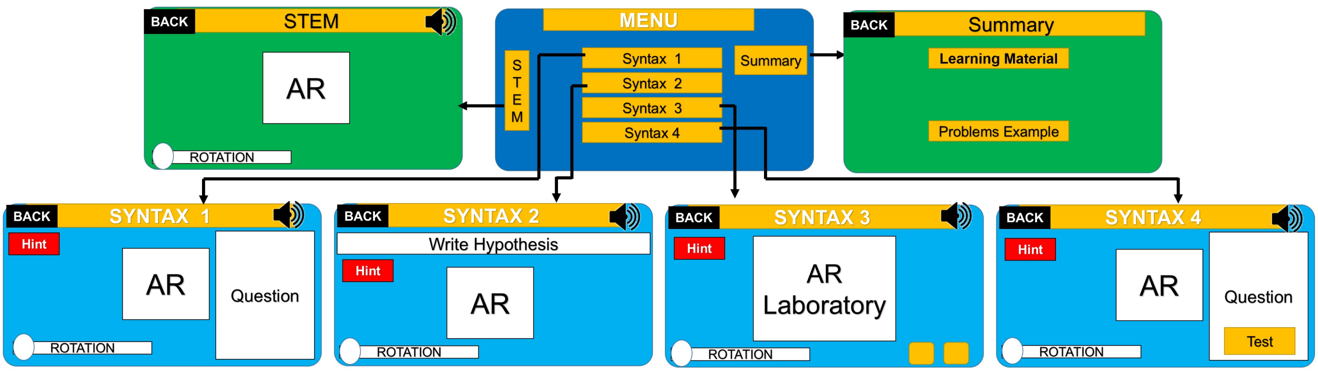
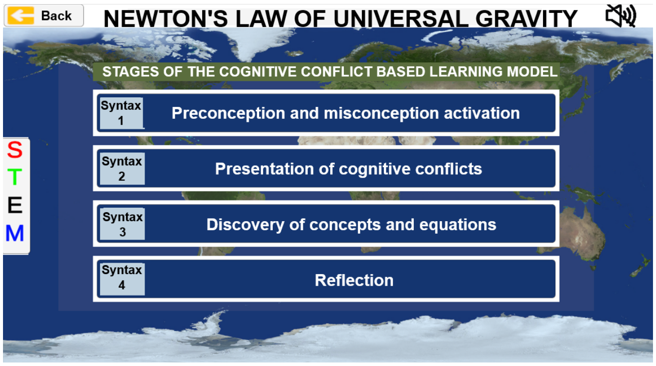


Fig. 2. Storyboard AR.

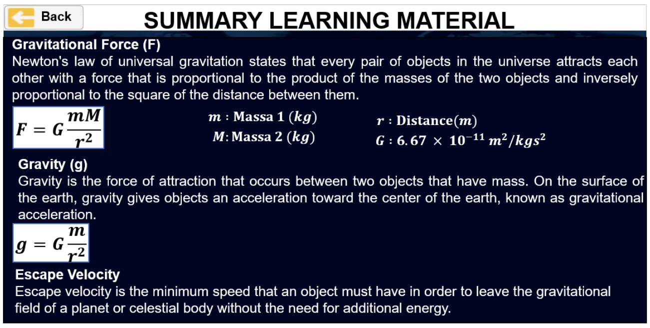
Fig. 2 shows the AR storyboard design loading menu page view. On the main menu page, learning was presented with content that includes STEM components implemented in Newton's law of universal gravitation phenomenon, syntax stages of the cognitive conflict model, and a summary of learning materials. The results of the storyboard design were developed into a digital learning medium as a teaching material on Newton's law of universal gravitation.

The syntax stages of the cognitive conflict model act as the main menu design that guides systematic learning in this application. The four syntaxes of the cognitive conflict model play a role in changing students' initial concepts into scientific concepts through a series of experiments. Each stage in this syntax contains visualizations, simulations, and experiments presented through AR technology. The science, technology, engineering, and mathematics content presented on the application menu was an introduction to STEM approaches. Overall, the presentation was structured in each stage of the cognitive conflict model. The syntax of the cognitive conflict model was a core part of this application that integrates AR presentations, STEM approaches, and scientific literacy materials, especially in learning Newton's universal law of gravitation.

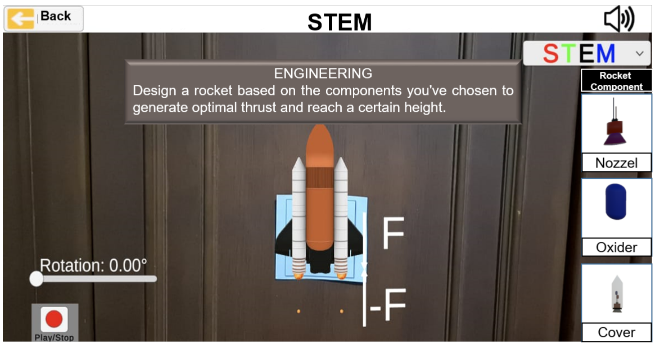
The AR product was then developed into an Android application in the Android Package Kit (APK) format, which was presented in a series of syntax of cognitive and STEM conflict learning models. This AR brings interactivity to learning and allows for connected navigation between pages. The design of the AR product display, which guides access to other menu pages, is presented as seen in Fig. 3.



(a). Menu AR



(b). Summary Learning Material



(c). STEM

Fig. 3. AR display page.

Fig. 3 shows the main page of the AR digital teaching materials, which consists of the main menu display, STEM, and material summary. On the main page, there was a navigation button that connected the pages. Navigation on the main menu allows access to STEM pages, material summaries, and syntax stages of the cognitive conflict model. On the summary page of the material, Newton's law of universal gravitation and interactive example problems are presented, as shown in Fig. 3 c). The material on the STEM Approach page was presented as AR phenomena that outline information about science, technology, engineering, and mathematics, visualized as 3D objects using AR, as shown in Fig. 3 b). Integrating learning content in the STEM approach was carried out at each stage of the cognitive conflict model. AR presents a scientific phenomenon in the form of the phenomenon of the gravitational force of the planet caused by a mass object. The technology study displayed a rocket technology design that could resist the gravitational field. In engineering studies, rocket designs were presented to be able to exceed the minimum limit to pass the release speed of a planet due to the influence of gravitational fields. In mathematics, information was presented in the form of AR, which describes formulas and variables that affect the release speed of a planet.

Although the focus of this research did not result in actual physical innovation, engineering in the STEM context applied in the study focuses more on the design and simulation process in a virtual environment. Through the use of AR technology, students could understand the principles of engineering by designing rockets virtually, which was a practical representation of the application of science and mathematics. While it did not present any new physical innovations, this approach provides students with the experience to apply engineering knowledge in real life in more accessible simulations in a school setting. Thus, engineering in this study aims to overcome the limitations of learning in the real world, where rocket design was challenging to realize in person but could be realized in virtual form.

All of the information described was presented in AR and was relevant to STEM studies. Information about Newton's laws of STEM gravitation was implemented in AR presentations at each stage of the cognitive conflict model. Four knobs represent each stage of the cognitive conflict model. The presentation of the first syntax begins with the activation stages of preconception and misconception. The learning display in that stage is shown in Fig. 4.

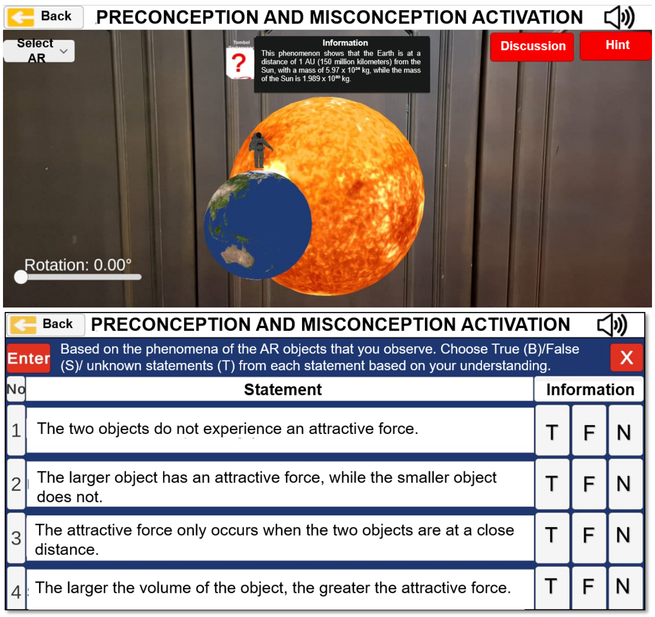


Fig. 4. Syntax 1 (Preconception and misconception activation).

Fig. 4. shows the first stage of the cognitive conflict model, namely the activation of preconceptions and misconceptions. This stage displays the phenomenon of Newton's law of universal gravitation in the form of AR. At this stage, learning occurs through student interaction with the AR phenomenon displayed. The animations and simulations of the presented phenomena allow the user to zoom in, zoom out, and press objects to display commands and more information related to

the object.

This section presents objects in the form of AR phenomena and 3D AR buttons, raising questions that spark students' initial knowledge from the observation of the AR phenomenon. Each question in this stage contains possible true (T), false (F), and unknown statements (N) related to students' understanding of the phenomenon of Newton's law of universal gravitation. Each answer information filled in by students related to the displayed phenomenon will display the value of the understanding answered and discuss appropriate statements related to the AR phenomenon observed at the activation stage, preconception, and misconception. This stage generally plays a role in checking and building students' initial understanding of learning. In the next stage, students will conduct further analysis by providing conjectures related to phenomena through the presentation stage of cognitive conflicts. These stages are shown in Fig. 5.

Fig. 5 shows the second stage, which presents cognitive conflicts. At this stage, two phenomena of Newton's law of universal gravitation were presented in the form of AR. From the information presented, there were three question buttons related to students' hypotheses regarding the phenomenon. At this stage, the questions presented were open to encourage students to build scientific literacy related to indicators explaining scientific phenomena. The information written by students will be stored in the history button. The results of these answers were students' hypotheses in analyzing further phenomena in experimental activities. The stages of hypothesis testing are presented in the stage of discovering concepts and problems, as shown in Fig. 6.

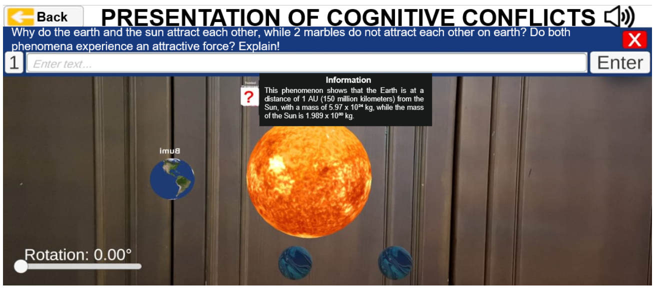
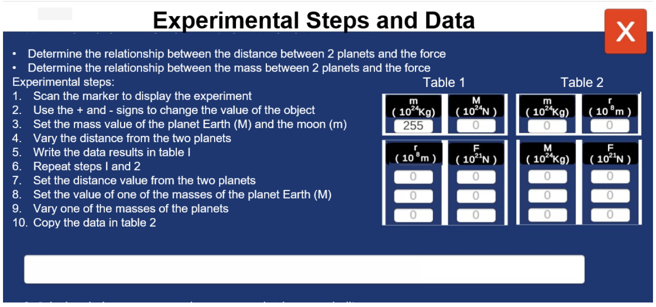
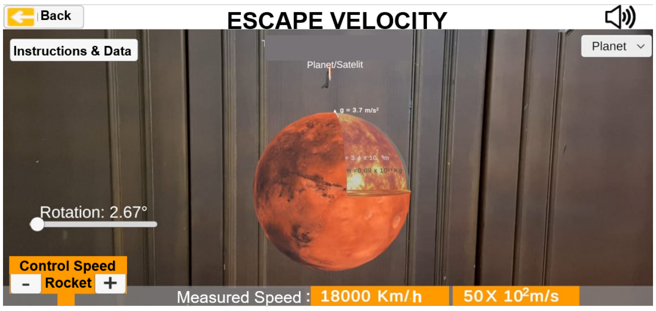


Fig. 5. Syntax 2 (Presentation of cognitive conflicts).

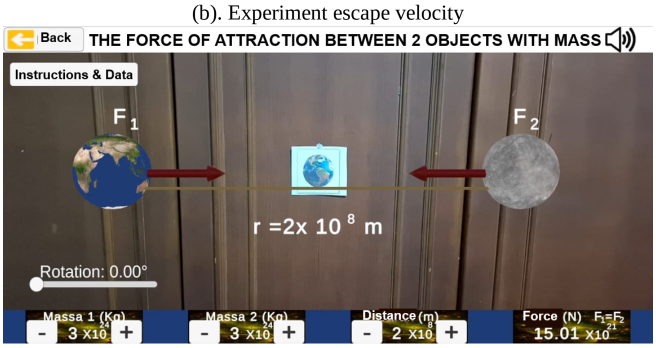
Fig. 6 shows the stages of concept discovery and equations to test hypotheses related to Newton's law of universal gravitation. In the experiment, information on the experimental steps and data collection table is available in Fig.6 a). There were two virtual laboratories in the form of AR consisting of the escape velocity experiment and the gravitation force experiment, as shown in Fig. 6 b) and Fig. 6 c) Experimental activities in the form of AR that display the phenomena discussed in the STEM approach separately and together, such as rockets, planets, calculations, and technical strategies, to obtain appropriate results based on real concepts. The Gravitation Force experiment presents data collection related to the interaction between two planets located at varying distances and masses. As shown in the AR, objects could be controlled and inputted with different mass and distance variables according to the instructions from the stages of the experiment presented in this AR. The data variation control button in the experiment retrieval was presented with + and - sign data. In addition, interaction was also presented by adding explanatory information through voice when the user pressed the audio button.



(a). Procedure and table data experiment



(b). Experiment escape velocity



(c). Experiment gravitation force

Fig. 6. Syntax 3 (Discovery of concepts and equations).

Another experiment was related to the study in STEM, namely the design of a rocket to be able to escape to orbit, which is discussed from the side of science about planetary phenomena, technology on the rocket side in terms of techniques related to rocket systems, and mathematics related to the minimum calculation to be able to have the escape speed. The presentation of information on the experimental phenomenon was controlled by students in AR objects by changing the variable data of each planet, the position of the rocket, and its release speed, as shown in Fig. 6 b).

At this stage, the main goal is to train students' abilities in scientific literacy indicators related to scientific investigation. The data obtained from the experiment could be input into the data table available in this AR application. The data was concluded based on the results of the experiment. The data summarization process aims to train students' abilities in scientific literacy indicators and the ability to interpret data. The quantitative results of each stage of the syntax of the cognitive conflict model were evaluated through comprehension tests. The test stages are presented in the reflection stages, as shown in Fig. 7.

Fig. 7 shows the fourth stage of the syntax of the cognitive conflict model, which is reflection. This stage acts as feedback on the student's learning outcomes from the previous stage. At this stage, AR phenomena were presented that function to stimulate students to utilize the abilities from the previous stage and explain, investigate, and interpret the data from the phenomena presented.

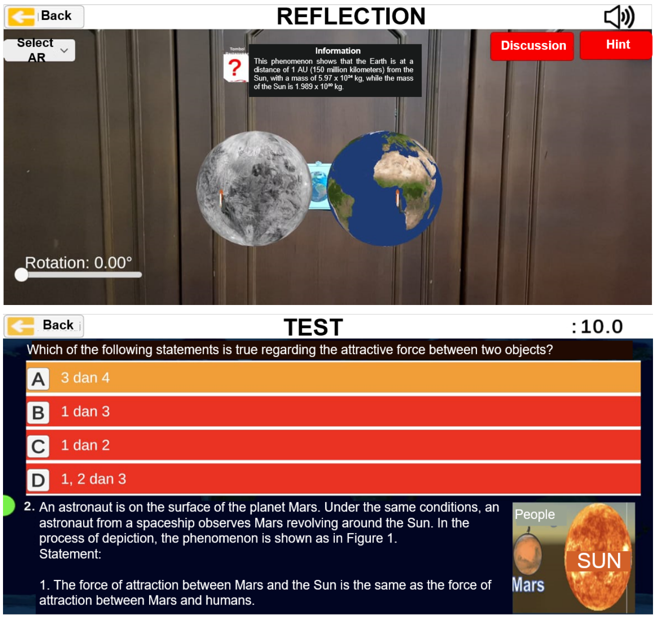


Fig. 7. Syntax 4 (reflection).

In AR, a question button was also presented at the reflection stage to measure students' understanding of analyzing phenomena by selecting true (T) or false (F) statements. On the reflection page, there was also a scientific literacy test to measure the final ability after teaching Newton's law of universal gravitation. The results of the answer would display the student's score from each question. These results reflect the development of students' abilities before and after learning by utilizing AR in each step of the cognitive conflict model that integrated STEM into the learning, with the aim of training students' scientific literacy.

Products that have been successfully designed through the testing stage. The initial testing stage of the product is through self-evaluation. The self-evaluation stage is an initial test to assess the quality of the AR prototype. This assessment was carried out independently by the developer. This test aims to check the completeness of the product being developed. This stage also assists developers in identifying potential shortcomings or errors that may have been missed during the development process. This allows the product to be repaired early before being tested by users or experts, thereby improving the efficiency and effectiveness of the overall evaluation process. The results of the test on self-evaluation are presented in Table 2.

Table 2. Self-evaluation test results

No	Indicators	Score (%)
1	Completeness of materials	100
2	Navigation button functionality	100
3	Completeness of product structure as teaching materials	100
4	Product success in the installation process	100
	Average	100

Table 2 displays the results of product self-evaluation testing on four assessment indicators. The check includes the completeness of material about Newton's law of universal gravitation contained in the application, which was declared 100% complete. In the application navigation button test, the result was that all buttons function and run between pages well, so it was declared complete with a score of 100%. The completeness of the teaching material structure has also been met and declared 100% complete to meet the criteria as teaching material. In the product as an application test, the installation process was carried out, and the results obtained showed that the product was successfully installed and running smoothly, which was declared 100% complete. Overall, the self-evaluation results show that the product developed has met 100% completeness, so the product could be continued for further testing by involving experts to assess its quality.

The AR application has been successfully developed with usage specifications according to the standard of Android smartphones. The application developed can be accessed on Android smartphones with Android versions that support API level 10 to API level 14 and require a minimum of 2 GB of RAM. The size of this app was 80 megabytes.

B. What Are the Results of the Validity Test of AR with a Cognitive Conflict Model That Integrates STEM to Improve Students' Scientific Literacy Related to Newton's Universal Law of Gravitation?

The validity results were obtained from six experts. Three of them provide special assessments of the material's substance and the learning's design. Meanwhile, three other experts assessed visual communication display indicators and software utilization. The division of these assessment indicators was based on the expertise of each expert. The validity results for the substance of the material and the learning design are shown in Table 3.

Table 3. Material substance and learning design

No	Indicators	V1	V2	V3	Average
A	Material Substance	0.94*	0.97*	0.96*	0.96*
B	Learning Design	0.90*	0.89*	0.92*	0.91*
			Average		0.93*

Note: V1: Expert 1, V2: Expert 2, V3: Expert 3, *Valid

Table 3 displays the validation results from three experts on assessing material substance indicators and learning design. The three experts' validity results on the material's substance ranged from 0.94 to 0.97, with an average value of 0.96, indicating that this product was valid. The product's validity on the material's substance informs the suitability of the content, material, physics equations, writing, and objects presented with the material context of Newton's law of universal gravitation. The validity results of the three experts in the learning design also ranged from 0.89 to 0.92, with an average score of 0.91, indicating that this product was valid. The validity of the product in the learning design showed the suitability of the cognitive conflict model stage, the learning content in the STEM approach, and the support for the achievement of learning goals in training students' scientific literacy. The average result of the material substance and learning design indicators of 0.93 indicates that this product was valid and by the content of the applied learning materials.

Other validity assessments are carried out on the software and application design developed. The assessment includes indicators of visual communication display and software utilization. This testing process ensures that the developed product meets the set standards. The validity results for visual communication display indicators and software utilization can be seen in Table 4.

Table 4. Visual communication display and software usage

No	Indicators	V1	V2	V3	Average
1	Visual communication display	0.94*	0.94*	0.96*	0.95*
2	Software Utilization	0.96	0.95**	0.97*	0.96*
			Average		0.95*

Note: V1: Expert 1, V2: Expert 2, V3: Expert 3, *Valid, **Very Valid

Table 4 displays the validation results from three experts on the assessment of visual communication display indicators and software utilization. The validity results of the three experts on visual communication displays ranged from a value of 0.94 to 0.96, with an average value of 0.95, indicating that this product was valid. The validity of the product on the visual communication display informs that the selection of colours, fonts, displays, AR object content, and layout are presented proportionally and attractively. The validity results of the three experts on the use of software also ranged from a value of 0.95 to 0.97, with an average value of 0.96, indicating that this product was valid. The validity of the product in the use of software shows the interactivity, simulation, and installation of the product that was optimally presented as an application. The average result of the visual communication display indicator and software utilization of 0.95 indicates that this product was valid and by the content of the applied learning materials. Overall, the results of the total validation assessment of the product are shown in Table 5.

Table 5. Total validation results

No	Indicators	Average
1	Material substance and learning design	0.93*
2	Visual communication display and software usage	0.95*
		0.94*

Note: *Valid

Table 5 shows the full results of AR product validation. The total value of the product validation was 0.94 in the valid category. So that the AR products that have been developed were valid on material substitution indicators, distribution design, visual communication display, and software utilization, AR products that have been tested to be valid are further tested at the practicality stage.

C. What Are the Results of the Practical Test of AR with a Cognitive Conflict Model That Integrates STEM to Improve Students' Scientific Literacy Related to Newton's Universal Law of Gravitation?

The results of the practicality test consisted of one-to-one evaluation and small-group evaluation. The one-to-one evaluation involved three students, and the small-group evaluation involved 18 students. The tests were carried out sequentially, starting with testing the product on three students to obtain initial information on the graduation data. Further tests involve small-group evaluation. Practicality testing involves assessing indicators of ease of use, attractiveness, efficiency, and benefits. Each indicator has several aspects of assessment. The assessment results of the ease of use indicators are presented as shown in Table 6.

Table 6. Results of the ease of use indicator

No	Indicators	Practicality Test	
		One to one	Small group
1	Pointers are presented in an interactive and easy-to-understand manner	100**	91.11**
2	Syntax stages 1 to 4 are presented systematically	98.33**	89.17**
3	Navigation buttons and page interface are easily accessible	100**	84.44**
4	The presentation of the material is easy to understand	100**	85.56**
5	AR virtual experiments are easy to implement	100**	93.33**
	Average	99.66**	88.72**

Note: *Practical. **Very Practical

Table 6 displays five aspects of assessment on the convenience indicator. In the one-to-one evaluation, the scores spread from the lowest score of 98.33 in the practical category to the highest 100 in the very practical category. In the small-group evaluation, the scores also spread from the lowest score of 84.44 in the practical category to the highest score of 93.33 in the very practical category. The average scores on the one-to-one and small-group evaluation indicators were 99.66 and 88.72. The results indicate that the product was in the practical category. The results indicate that instructions, model stages, navigation, materials, and experiments were presented easily and implemented systematically.

Product quality was also checked using the attractiveness indicator in the practicality test. This assessment aimed to measure how much the product could attract students' interest in learning. The product's attractiveness includes an assessment of several aspects, including the uniqueness of the product and its suitability with the student's character in learning. The results of the attractiveness assessment indicators are presented in Table 7.

Table 7. Attractiveness indicator results

No	Indicators	Practicality Test	
		One to one	Small group
1	Display pages were presented according to the content	100**	96.67**
2	Materials were presented interactively	93.33**	95.56**
3	The type of writing was readable and interesting	100**	91.11**
4	AR was displayed interactively and realistically	100**	95.56**
5	Menu and app icons	100**	91.11**
6	The colours were presented in contrast to the appearance	100**	97.78**
7	The layout was presented proportionally	100**	88.89**
8	AR lab was presented interactively	100**	94.44**
	Average	99.17**	93.89**

Note: *Practical. **Very Practical

Table 7 shows six aspects of assessment on the attractiveness indicator. In the one-to-one evaluation, the scores spread from the lowest score of 93.33 in the practical category to the highest 100 in the very practical category. In the small-group evaluation, the scores were also spread from the lowest score of 88.89 in the practical category to the highest score of 97.78 in the very practical category. The average scores on the one-to-one and small-group evaluation indicators are 99.17 and 93.89. The results indicate that the product was in the practical category. The practicality of this product shows that the display pages, materials, typefaces, colours, application icons, and laboratory layouts were presented with contrast, interactivity, and appeal that support learning.

Product quality was also checked using the efficiency indicator in the practicality test. This assessment aimed to measure the extent to which the product was effective when used in teaching. Product efficiency includes assessing several aspects related to time and cost. The results of the efficiency assessment indicators are presented in Table 8.

Table 8. Results of the efficiency indicator

No	Indicators	Practicality Test	
		One to one	Small group
1	Supporting study time becomes more effective	100**	94.44**
2	Cost-effective in using it	100**	91.11**
3	Support for virtual experiments	100**	91.11**
4	Cost-effective in owning it	100**	90**
	Average	100**	91.66**

Note: *Practical. **Very Practical

Table 8 displays six aspects of assessment on efficiency indicators. In the one-to-one evaluation, the scores spread from the lowest score of 90 in the practical category to the highest score of 92 in the very practical category. In the small-group evaluation, the scores were also spread from the lowest score of 90 in the practical category to the highest score of 92 in the very practical category. The average scores on the one-to-one and small-group evaluation indicators are 90 and 92. The results indicate that the product was in the practical category. This product's practicality showed that it was cost-effective and streamlined learning time. It supported the implementation of virtual experiments to be used independently without limitations on time, place, and limited tools.

Product quality was also checked on the benefit indicators in the practicality test. This assessment aimed to measure the extent to which the product could benefit students in learning. The product's benefits include assessing several aspects related to support for learning. The results of the benefit assessment indicators are presented in Table 9.

Table 9. Results of the benefit indicator

No	Indicators	Practicality Test	
		One to one	Small group
1	Supporting self-study	100**	91.11**
2	Helps to understand concepts better	100**	91.11**
3	As a learning resource	100**	86.66**
4	Supporting the mastery of scientific literacy	100**	91.11**
5	Supporting the implementation of experiments	100**	96.66**
	Average	100**	91.33**

Note: *Practical. **Very Practical

Table 9 displays six aspects of assessment on the benefit indicators. In the one-to-one evaluation, each indicator's overall score obtained a 100 in the very practical category. In the small-group evaluation, the scores spread from the lowest score of 86.66 in the practical category to the highest score of 96.11 in the very practical category. The average scores on the one-to-one and small-group evaluation indicators are 100 and 91.33. The results indicated that the product was in the practical category. The practicality of this product showed that the product provided benefits for students in supporting independent defenders, understanding concepts, resources, and virtual experiment media.

The results of the product practicality test were spread out from four assessment indicators: ease of use, attractiveness, efficiency, and benefits. Overall, the product received a good response from students to the AR product developed. The results of the assessment on the practicality test of AR products are shown in Table 10.

Table 10. Results of practicality indicators

No	Indicators	Practicality Test	
		One to one	Small group
1	Ease of use	99.17**	88.89**
2	Attraction	99.17**	93.89**
3	Efficiency	100**	91.67**
4	Benefit	100**	91.33**
	Average	99.58**	91.44**

Note: *Practical. **Very Practical

Table 10 displays four main indicators of the results of the practicality assessment. In the one-to-one evaluation, the score spreads from the lowest value of 90 on the convenience indicator to the highest score of 92 on the attraction indicator. In the small-group evaluation, the score was also spread from the lowest value of 90 on the convenience indicator to the highest score of 92 on the attraction indicator. The average scores on the one-to-one and small-group evaluation indicators were 90 and 92. These results indicated that the product has been practical in the indicators of ease of use, attractiveness, efficiency, and benefits. In addition to the results of student assessments, there were responses from students about the application of AR. The results of students' responses after using the AR application are presented in Table 11.

Table 11. Synthesis of the responses students

Category	Data
Attraction	I feel that AR is an interesting medium to use in learning.
	I believe that AR is needed as an effective learning medium.
Interactivity	The AR simulation is so realistic that I feel as if I am inside a real experiment.
	AR provides a laboratory experience without having to be in a physical laboratory.
Ease of use	With AR, I can see the concept of physics directly.
	Previously difficult material becomes clearer and easier to understand thanks to AR visualization.
Efficiency	I can learn anytime and anywhere with AR, making it very flexible.

Table 11 shows responses to students' comments and suggestions about AR in learning. Students generally express their attraction to AR technology as a new technology known in the learning process. This condition supports the response of students' needs about AR technology in learning. In the interactive presentation, students revealed that AR could support the phenomenon as it was, which provided a new learning experience for students by utilizing smartphones. Students also expressed better ease when learning by utilizing AR, as phenomena about celestial bodies and planetary satellites that could not be observed directly could be better understood with the help of AR. In addition, students revealed that AR provided efficient support in learning without the limitations of time and place. These results informed that the product provided practical learning support in improving students' scientific literacy on Newton's law of universal gravitation.

D. What Are the Results of the Effectiveness Test of AR Design with a Cognitive Conflict Model That Integrates STEM to Support Scientific Literacy Regarding Newton's Universal Law of Gravitation?

The pretest and posttest data have been tested using statistical analysis. The initial testing was conducted through a normality test using the Shapiro-Wilk method. This test was chosen because it was suitable for relatively small samples. The results of the normality test are presented in Table 12.

Table 12 displays the data on the normality test results of the science literacy assessment, which consists of pretest and posttest data from student learning outcomes. The test results indicated that the significance value (sig) > 0.05 for both tests, indicating that the data was normally distributed. Therefore, statistical testing to compare pretest and posttest results was conducted using paired sample t-test. The paired sample t-test was used to investigate overall improvement effects, while the presentation of %N-gain information aimed to examine the increase in scientific literacy abilities for each student. The distribution of %N-gain results for student scientific literacy abilities is displayed in Fig. 8. Meanwhile, the results of this paired sample t-test are presented in Table 13.

Table 12. Tests of normality

Test	Shapiro-Wilk		
	Statistic	df	Sig
Pretest	0.93	26	0.36
Posttest	0.94	26	0.52

Note: If sig>0.05, then the distributed data was normal

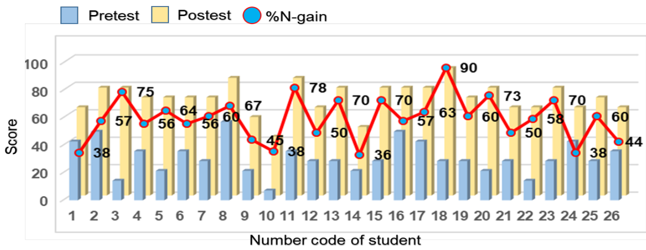


Fig. 8. Results of N-gain analysis of scientific literacy.

Table 13. Paired Samples t-test

Pretest		Posttest		%N-gain	Paired Samples t-test				
					Confidence Interval of the Difference		t	df	Sig
M	SD	M	SD		Lower	Upper			
31	11.32	71.4	10.64	59%	−25.58	−10.99	-5.16	51	0.000

Fig. 8 shows the N-gain percentage of each student based on pretest and posttest data related to science literacy on the topic of Newton's universal law of gravitation. The lowest student improvement was recorded at a 38% N-gain percentage, while the highest improvement reaches 90%. These results indicate that improvement occurred evenly among each individual student, falling into the moderate improvement category. Overall, the average N-gain percentage for students' science literacy abilities was 59%, which falls within the moderate category. This finding suggests that AR-based learning has significantly supported the overall improvement of students' science literacy abilities. The improvement of students' scientific literacy skills is strengthened by the results of the paired sample t-test.

Table 13 presents the results of the paired sample t-test from the pretest and posttest. In the pretest, the average score obtained was 31 (SD = 11.32), while in the posttest, the average score increased to 71.4 (SD = 10.64). These results indicate that the average student scores after using AR in learning are higher compared to before the instruction. The obtained t-value was -5.16, significantly smaller than the standard value of -2.78. Additionally, the significance value was 0.000, which was smaller than 0.05, indicating a significant difference in students' scientific literacy abilities before and after AR-based instruction. These findings reveal that AR-based learning has a positive impact on enhancing students' scientific literacy on the topic of Newton's law of universal gravitation.

V. Discussion

A. What Is the Form of AR Design with a Cognitive Conflict Model That Integrates STEM to Improve Students' Scientific Literacy Related to Newton's Universal Law of Gravitation?

AR based on cognitive and STEM conflicts has been designed to support students' scientific literacy. This AR has been designed in Android APK format. Previous research displayed learning products in a website format [15, 29]. Learning offerings in the form of websites require internet access. Meanwhile, the AR products developed can be accessed in offline conditions. The efficient APK format has become standard in Android-based media development [41]. The integration of science, technology, engineering, and mathematics (STEM) is discussed in each stage of cognitive conflict. In the stages of syntax 1, syntax 2, syntax 3, and syntax 4, the relationship of systematic material descriptions that correlate with the preparation of student scientific literacy development is displayed.

Describing planetary phenomena and rocket technology studies content indicators closely related to scientific literacy. The learning was arranged in each presentation in the form of interactive AR. The AR presented must show the object at work and depict real conditions [42]. Each stage in the syntax displays a phenomenon related to Newton's law of universal gravitation depicted in the AR object. Previous researchers were limited to presenting the phenomenon of Newton's law of universal gravitation in images and videos without interaction with the object being observed [43]. AR was developed by displaying interactivity and phenomena in the 3D form that allowed users to interact in the virtual realm.

In the first stage, in the form of activation of preconceptions and misconceptions, it played a role in encouraging students' ability to explain phenomena. The phenomenon of AR objects played a role in building initial knowledge and stimulating students to think about the phenomenon through the questions presented [44]. The stages of cognitive conflict with simulation presentations in the form of images, videos, and others played a role in encouraging students to think deeply in building initial knowledge [26]. At this stage, students would obtain initial information related to the phenomena around them, which are facts in real conditions that are unknown [25]. In order to further understand the analysis, the presentation of AR is described in the hypothesis stage. Media design that used AR was the latest innovation compared to previous researchers who only focused on presenting phenomena in the form of images and videos [9, 14, 35, 45].

In the second stage, presenting cognitive conflicts played a role in building students' knowledge to think critically and explain conflicting phenomena. AR objects were presented as two phenomena that encouraged students to express their thoughts openly through writing. Open-ended questions encourage students to explore their thoughts and explain phenomena more creatively and critically. This stage played a role in building students' ability to explain scientific phenomena using scientific literacy indicators. Experimental testing was carried out to prove the hypothesis.

The third stage, in the form of discovering concepts and equations, aimed to obtain information from experimental activities. At this stage, experimental data was collected from user interaction with controlled AR objects to obtain data in an AR laboratory environment. The previous lesson presented direct questions and visualizations as videos [45]. AR was used in 3D visualization that was realized in the user's environment so that the information in the developed AR could be represented more clearly than videos that were limited to two dimensions.

Laboratory simulation in AR was designed to be supported by previous researchers who support scientific literacy. Laboratory availability encourages student interaction to engage in experimental activities [3]. Data collection in experimental activities played a role in training students to process information in depth [46, 47]. The synthesis of data information obtained plays a role in encouraging students to interpret the data [48, 49]. The AR developed facilitates these activities and interactions for students in learning. Virtual laboratories could improve students' scientific literacy [50]. In testing the measurement of students' abilities, the fourth stage, in the form of reflection, acts as an evaluation test in presenting the AR phenomenon for students to measure their abilities after passing all these stages. The reflection stage played a role in measuring students' abilities as feedback for further learning [26].

Each stage presented in AR replicates a real phenomenon in 3D. This phenomenon was discussed in STEM studies, which were organized in each stage of the syntax of the cognitive conflict model. The interactivity presented in AR has flexibility in controlling objects, such as zooming in, rotating, touching objects, inputting data, and processing data from each AR object displayed. This flexibility was an advantage of the design of AR objects. The results of the AR design were assessed through a validity test.?

B. What Are the Results of the Validity Test of AR with a Cognitive Conflict Model That Integrates STEM to Improve Students' Scientific Literacy Related to Newton's Universal Law of Gravitation?

The designed AR was in the category of valid assessment. The digital products developed must meet the standards of material substance elements, display design, software utilization, and learning design [51]. The results obtained meet the standards of digital application products in learning. The material must be presented and complete to support learning [52]. The results of the product quality test were better than the previous researcher, who only involved three experts with a score of 0.90 [35]. Meanwhile, the AR product developed is better because it obtained an average of 0.94 from 6 experts.

The developed product presents all the material parts of Newton's law of universal gravitation. Digital teaching material that is aimed at learning must be accompanied by a model or approach supporting systematic learning [53]. AR was presented with the design of stages, syntax, cognitive conflict models, and STEM approaches. The proportional design display and the functionality of the navigation buttons were an important part of supporting user interaction with the media [54, 55]. AR functions smoothly and runs normally in AR presentations and the implementation of experiments in a virtual environment. Digital products must be developed innovatively and originally in their development [56]. The AR developed presents original phenomena and designs as an Android application format to support learning. In general, the cognitive conflict-based and STEM-integrated AR products that have been developed meet the standard elements of digital product validity.

C. What Are the Results of the Practical Test of AR with a Cognitive Conflict Model That Integrates STEM to Improve Students' Scientific Literacy Related to Newton's Universal Law of Gravitation?

The products developed also meet the practicality of use. The practicality in question included presenting practical and effective interactions in its use. Previous researchers informed the practicality test by involving nine students with product results in the practical category [57]. The AR developed involved 21 students in conducting practicality tests and obtained better scores than previous researchers on each practicality indicator. Product testing in small groups was not a limitation in supporting product quality. The practicality test involves students with various abilities, including low, medium, and high abilities. Thus, the product testing results have been ideal because they have represented the characteristics of students' abilities.

The one-to-one evaluation was the initial stage in the practicality test. In the one-to-one evaluation, the students involved consisted of only three people. The results of the one-to-one evaluation were decisive for continuing the test to the small-group evaluation. The one-to-one evaluation trial was to determine the practicality of using the AR application on each student's smartphone, while the small-group evaluation was to find out the practicality of AR implementation in small-scale learning. This was the order to produce a quality AR prototype. If the results were very good, the product could continue to small-group evaluation. Higher values at the one-to-one evaluation indicate that the product was worth further testing at the small-group evaluation. In the small-group evaluation, students were more involved and had a variety of abilities. The results of this test provided a wider variety of assessments according to each individual's ability to use the product, feel the benefits, and assess its efficiency.

Ease of use was the main component of using applications in learning [58]. Smooth navigation and display interaction and clear information on each navigation button promote ease of use [55, 59–61]. In addition, the usefulness of a digital product must be able to support the learning process [39, 62, 63]. The benefits of AR development include the implementation of virtual laboratory experiments in AR displays. This presentation made it easier for students to conduct experiments independently without space and time limits. The efficiency of using media or teaching materials in the learning process must consider the cost and time in their use [64, 65]. The involvement of the senses in varied learning was an important part of learning interactivity by utilizing AR. AR presents various interactivity in the form of touch on AR display objects through smartphone cameras and audio presentations to support interaction in learning. AR was packaged in an application format that was free of charge to access it. The development of digital learning media supports cheap financing for owning and using it in learning [66]. Systematic information presentation encourages users to use it efficiently. The AR developed meets the criteria of practicality in ease of use, usefulness, display, and efficiency in supporting learning.

Cognitive conflict-based and STEM-integrated AR supports scientific literacy with a design designed to support learning Newton's law of universal gravitation. This design could present phenomena that include STEM approaches discussed in reviewing problems regarding diverse knowledge. The presence of cognitive conflict stages supports systematic learning in training students' scientific literacy through the stages of presenting phenomena in the form of AR. The developed products have been tested for validity and practicality, meet valid assessment standards, and are highly practical for use. The availability of interactive AR facilities and experimental laboratories in the form of AR was a hallmark of this product, as it was displayed in every stage of the cognitive conflict model and was discussed in the study of science, technology, engineering, and mathematics. With AR being valid and practical, it could support scientific literacy learning in discussing the material phenomenon of Newton's law of universal gravitation.

D. What Are the Results of the Effectiveness Test of AR with a Cognitive Conflict Model That Integrates STEM to Improve Students' Scientific Literacy Related to Newton's Universal Law of Gravitation?

Utilizing AR for learning has been proven to have a positive impact in supporting students' scientific literacy improvement. Previous research also indicates that AR-based learning yields better outcomes compared to traditional learning, reinforcing the effectiveness of AR as an innovative educational tool. [36]. The improvement of scientific literacy abilities through AR is supported by its ability to present material more realistically through 3D displays. This allows for more comprehensive and engaging information presentation, thus assisting students in practising and enhancing their scientific literacy abilities.

The implementation of the cognitive conflict model in previous stages presented concept discovery activities in the form of 2D visualizations [35]. In the developed product, learning is applied with a more realistic presentation through AR to support more comprehensive material explanations. The combination of AR in inquiry-oriented learning significantly impacts the learning process [37]. This AR was developed following the stages of the cognitive conflict model, where each stage plays a role in reinforcing student learning concepts. The implementation of AR with the cognitive conflict model also enhances student engagement in practising their scientific literacy abilities [67]. These results confirm that the implementation of AR in learning significantly supports the improvement of students' scientific literacy abilities.

Research reveals that the availability of new technology in STEM approaches supports the achievement of optimal learning processes for students [68, 69]. Learning with technology offers broader support for students in exploring scientific literacy content [53]. In the implementation of STEM learning in physics, it has been found that student learning outcomes improve after utilizing AR [16]. The developed AR supports learning through visualization, investigation, and data interpretation, which play a crucial role in enhancing students' scientific literacy abilities and complementing the limitations of previous instructional media.

The implementation of STEM in previous learning emphasized a focus on the context of the material. However, the products now produced present technical skills in the form of a virtual environment through AR, which supports the process of concept discovery and problem-solving. This condition is reinforced by AR products that incorporate STEM components in the learning media. Thus, AR-based learning that introduces cognitive conflict stages and includes a STEM approach provides positive support in every stage of the learning process, effectively enhancing students' scientific literacy abilities, especially in the topic of Newton's law of universal gravitation.

VI. Conclusion

An AR application based on a cognitive conflict model integrated with STEM to support scientific literacy on Newton's universal law of gravitation was designed in APK format with realistic and phenomenal 3D visual characteristics. The application development process was systematically arranged through the stages of the cognitive conflict model, which involves STEM components directly in each learning stage. The app also allowed data collection through an AR laboratory developed for interactive simulations. The results of the validity test showed that this application was valid regarding material substance, display design, and software utilization indicators. In addition, the results of the practicality test showed that this application was convenient, attractive, efficient, and beneficial in improving students' scientific literacy of Newton's law of gravitation. The results of AR implementation in education reveal its positive impact on supporting the improvement of students' scientific literacy abilities. Therefore, AR is effectively used to enhance students' scientific literacy abilities on the topic of Newton's universal law of gravitation. Overall, the product developed has been valid, practical, and effective in supporting students' scientific literacy in learning the physics of Newton's law of universal gravitation.

This study was limited to testing effectiveness in a small group. Further research can be conducted by testing the effectiveness of this method on a larger scale and comparing it with various other teaching methods. Additionally, it is recommended to include new research variables, such as usage duration, confidence level, self-esteem, and user satisfaction. This study can also be expanded by exploring other technologies, such as virtual reality, mixed reality, or spatial reality, to support and enhance a deeper learning experience.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Fatni Mufit plays a role in planning, compiling, and analyzing research data. Wahyuni Satria Dewi contributed to planning the research and processing data. Selma Riyasni contributes to organizing and examining data analysis. Muhammad Dhanil contributes to developing media, collecting data, and processing data. All authors had approved the final version.

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