Integration of Smartphone-Based Learning Media and Project-Based Learning to Enhance Creativity and Scientific Literacy in Physics

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***Abstract*—This study aims to determine the level of creativity and scientific literacy of students using modern physics learning media based on smartphone-integrated Project-Based Learning (PjBL). The design used in this study is quasi-experimental design with a nonequivalent control group design. The population of this study was all 6th-semester undergraduate students taking modern physics courses. The samples used were two classes, namely class A as the experimental class (25 people) using smartphone-integrated PjBL-based media and class B as the control class (25 people) using the conventional model. The use of these media has a significant impact, such as increasing the results of the final test with data calculations using the t-test, which obtained a significant level of 0.05 with the results of the t-test showing a calculated $t_{value} > t_{table}$. This means that the media used affects the creativity and scientific literacy abilities of students. The results of the N-gain (g) analysis show that the value of increasing creativity and scientific literacy has a medium and high category for each material and each indicator. The results show that the use of modern physics learning media based on PjBL integrated with smartphones is very effective in improving students' creativity and science literacy skills in the classroom because the media used is innovative by utilizing the development of digital technology and makes it easier for students to learn the material, increase motivation, train cooperation, and responsibility, and attract students' attention. In addition, the advantage of this learning media is that it does not require an internet connection to run the application, which has an impact on the ease of the learning process. So it is necessary to develop an e-book to help students in learning more independently.**

***Keywords*—creativity, modern physics learning, Project-Based Learning (PjBL), scientific literacy**

I. Introduction

Science and Technology, or what is known as IPTEK (Ilmu Pengetahuan dan Teknologi), is one of the most important fields, which is the most important part that supports human activities in everyday life. Along with the development of the era, science and technology are increasingly sophisticated and support the creation of new technologies. Technological advances have influenced this life and cannot be avoided because IPTEK provides many benefits and makes work easier [1]. Mastery of IPTEK is an important key in the 21st century [2]. The development of IPTEK in the era of globalization like today requires humans to further improve their abilities and skills in order to be able to compete not only nationally but also internationally [3]. The process of technological progress produces modernity, marked by economic growth, social mobility, and expansion of culture. The progress of communication technology is increasingly sophisticated and easy; the development of communication technology can lead to relations between developed countries and underdeveloped countries whose production techniques are still low so that it cannot be avoided.

The development of science and technology in the 21st century requires humans to further improve their abilities and competencies so that humans can balance themselves in this modern era. Science and Technology has been very rapid in various fields, one of which is in the world of education. All forms of learning processes can be done easily with digital technology that has begun to be used in the field of education as a means to support learning, either as an information tool (a means of accessing information) or as a learning tool (supporting learning activities and assignments). The very rapid development of IPTEK has given rise to equipment and applications that are very easy to learn and use as learning media.

One of the basic sciences that has a very important role in supporting science and technology is in the form of science learning [4–6]. Science is the study of natural objects and phenomena obtained from the thoughts and research of scientists carried out with experimental skills using scientific methods [7–9]. The essence of science is the foundation for studying natural sciences [10].

One of the abilities that students are expected to master after studying science is scientific literacy [11–15]. Scientific literacy is a person's ability to solve a problem using scientific knowledge [16–19]. Scientific literacy in science learning is expected to be able to solve real-life problems in the 21st century. Through this scientific literacy, students have an important role in understanding scientific facts and the relationship between science, technology and society [20–23]. This scientific literacy aims to improve natural knowledge, oral and written vocabulary to understand and communicate science, and understand the relationship between science, technology, and society [24–26]. Scientific literacy needs to be improved and instilled in students in science learning, especially in physics material so that students can be directly involved in the impact of science in everyday life.

Physics is a branch of natural science that studies matter and all physical activities of the matter [27, 28]. One part of physics is modern physics, which studies the behavior of matter and energy on an atomic scale and subatomic particles or waves [29, 30]. In principle, it is the same as in classical physics, but the material discussed in modern physics is the atomic or subatomic scale and particles move at high speed [31].

The reality in the field related to the modern physics lecture process shows that the development of scientific literacy of students is still low. This is indicated by the fact that many students are still unable to relate learning materials to real life in everyday life, as well as understand and solve existing problems. The low scientific literacy of students is also caused by the lack of relating learning materials to examples in the surrounding environment. Even learning activities so far have not provided students with opportunities to create scientific works or make products using used materials related to science. Therefore, it is necessary to encourage student creativity to apply scientific literacy in their surroundings. Low scientific literacy and student creativity have an impact on students' lack of understanding of science learning, especially in modern physics lectures.

Based on the problems faced by these students, innovation is needed in learning activities, to improve students' creative thinking and scientific literacy. Lecturers can improve students' creative thinking and scientific literacy by learning using constructivist learning strategies such as the Project-Based Learning (PjBL) model [32–34]. PjBL is a learning process with long-term activities that involve students designing, creating and displaying products to solve real-world problems [35, 36]. Another consideration for lecturers to use a project-based learning model is because this model is one of three learning models that are highly recommended in facing the challenges of the 21st century [37]. Several research results conducted by reference [38] show that the use of models can improve student literacy.

In addition to using these learning models, students' modern physics learning outcomes can be improved through the help of media. One of the media that can be used to support 21st century learning is a smartphone. Several research results conducted by reference [37] show that the use of smartphone media can improve student learning outcomes. Because the use of smartphone media can trigger an interactive and independent learning environment between students and teachers.

The choice of using a smartphone when compared to other media such as laptops, tablets, or other online media is certainly due to the fact that smartphones are one of the gadgets that are almost owned by all groups today, especially for students at the college level. In addition, in terms of effectiveness, smartphones are easier to carry and use in various conditions, thus maximizing the use or access to the material being taught if applied to a smartphone.

Based on the considerations described above, to overcome the problem in order to achieve the objectives of modern physics learning, researchers need to develop modern physics learning media based on project-based learning integrated with smartphones to improve students' creativity and scientific literacy.

II. Literature Review

A. Model Project-Based Learning (PjBL)

According to reference [39], project-based learning, or PjBL, is a teaching approach that is built on real-life learning activities and tasks that have provided challenges for students to solve. These activities generally reflect the types of learning and work that people do according to what happens in everyday life outside the classroom [2]. PjBL is generally carried out by groups of students working together towards a common goal. According to reference [40], project-based learning is a learning model that is centered on students and provides meaningful learning experiences for students. Student learning experiences and concepts are built based on products produced in the project-based learning process. Project-based learning is a learning model that is centered on students to conduct an in-depth investigation of a topic. Students constructively deepen their learning with a research-based approach to problems and questions that are weighty, real, and relevant [41].

PjBL is a comprehensive approach to teaching and learning designed for students to carry out projects in solving problems [42]. Thus PjBL helps students in bridging the knowledge learned in school with the real world [43]. Likewise, Sugianto *et al*. [44] said that designing the PjBL model can improve learning achievement because students can develop a sense of independence in learning and real contexts.

The project-based learning model has four principles, namely: (1). The century principle emphasizes that project work is the essence of the curriculum, focuses on questions or problems; (2). The principle of constructive investigation (constructive investigation or design) in it explains the design process, decision making, problem finding, problem solving and module development process; (3). The principle of autonomy in project-based learning can contain student independence in carrying out the learning process, namely being free to determine their own choices, working minimally supervising and being responsible; and (4). The principle of realism in this principle PjBL involves real-life challenges, focuses on authentic statements or problems and problem solving can be applied in real life.

B. Digital Learning

Digital learning is a new development in education that uses digital technology and media to deliver material and achieve learning objectives [45]. Digital learning is a form of information technology used in education in the form of network space [46]. The term digital learning is more accurate to change the learning process into a school or university into a digital form of internet technology bridge.

Digital learning is a computer-based technology used to convey stories to students in the form of text, graphics, animation, audio, or video [47]. Therefore, it is very likely that teachers will implement learning in the form of continuous stories. This is relevant to the curriculum to stimulate student activity in learning. Another benefit, the use of digital can also make learning more interesting and can increase students' curiosity with the support of animation and music simultaneously [48]. The use of digital can also make learning more interesting and can increase students' curiosity about new learning, which promises great potential in changing the way a person learns, obtains information, adjusts information, and so on. Technology also provides opportunities for educators to develop learning techniques so as to produce maximum results and hone skills according to the times and is designed to provide opportunities to develop the power.

Some of the benefits of implementing digital learning are: (1) learning becomes more interactive and fun; (2) sharing knowledge can be easier; (3) developing greater interest in learning; (4) presentation of information is clearer and more interesting; (5) learning will be more interactive; and (6) easier and faster access to information [49–51]. Other studies have shown that the use of appropriate learning resources is very helpful in increasing learning enthusiasm by allowing direct interaction and empowering students to learn independently [52–53].

C. Smartphone Integrated e-Book

E-book is an electronic book in the form of an electronic version of a book. In general, the books used mostly consist of a collection of papers containing text or images, so that electronic books contain digital information but can be in the form of text or images that can be opened electronically via a computer or Android/smartphone. There are various popular e-book formats, including Portable Document Format (PDF), which can be opened with the Acrobat Reader program or similar. There is also an HTML format, which can be opened by browsing or Internet Explorer offline. Most e-modules use the PDF format because it is more accessible to all groups and easy in the security process [54].

E-Book is a form of presentation of independent learning materials that are systematically arranged into certain learning units, which are presented in electronic format, where each learning activity in it is connected by a link as navigation that makes students more interactive with the program, equipped with video tutorials, animations, and audio to enrich the learning experience, making students more interactive. The difference between printed and electronic modules generally lies only in the presentation format [55].

Digital books are also commonly called e-books or electronic books are published books in digital (electronic) form consisting of text, images and multimedia that can be read on computers, laptops, or other portable electronic devices (tablets and smartphones). In simple terms, an e-book is a book in electronic/digital form, unlike books that are usually printed on paper or other physical media. E-books in digital form are the result of developments in the field of information technology that cannot be separated from advances in internet and computer technology [56].

D. Scientific Creativity

Creativity is one of the important competencies of the 21st century. Creativity generally only looks at the aspects of fluency, flexibility and originality, while scientific creativity combines aspects of creativity and science. Scientific creativity is described in a structure as a theoretical basis for developing a scientific creativity measurement tool, this structure is called the three-dimensional Scientific Structure Creativity Model (SSCM).

Scientific creativity is an intellectual trait or the ability to produce or the potential to produce certain products that are original and have social or personal value, designed for a specific purpose using scientific information obtained [57]. Creativity is one of the important competencies that must be possessed by students. Views fluency, flexibility, and original thinking as the main characteristics of creativity [58]. This was later explained by reference [57], fluency or fluency is interpreted as the number of original ideas, flexibility or flexibility is the ability to change fixation, not tied to the approach that is often used (general) after knowing that the approach is no longer efficient for done, while originality or originality is interpreted statistically as "rarely occurring only occasionally in a certain population", or the answer is considered "original".

Money in reference [59] states that there are at least four components of creativity (a). Creative process; (b). Creative products; (c). Creative people; and (d). Creative situations. This description provides an overview of the creativity possessed by a person. To determine the level of creativity of a person, it is necessary to measure creativity. Although measuring creativity is quite complicated, there are already several standard instruments and assessments (which have been designed) to measure creativity in certain fields such as problem solving. Scientific creativity is sensitivity to the problems faced, the ability to generate new ideas that are technologically acceptable, the ability to ask questions, the ability to understand the world around us, the ability to solve problems, see solutions, design experiments, imagine, identify difficulties, create and predict hypotheses [60]. The aspects of scientific creativity used in this study follow the aspects in two general dimensions developed by reference [57], which are then described into four dimensions, each of which has three aspects, namely fluency, flexibility, and originality.

E. Science Literacy

Programme for International Student Assessment (PISA) is an education system evaluation program organized by the Organization for Economic Co-operation and Development (OECD) that aims to assess students' abilities in reading, mathematics, and science. Some of the benefits obtained through PISA activities include (1). Providing information about education systems in various countries; (2). Allowing comparisons of education performance between countries; (3). Providing insight into factors that influence education outcomes; and (4). Providing useful information for improving the education system in each participating country. The assessment of scientific literacy in PISA is not merely a measurement of the level of understanding of scientific knowledge, but also an understanding of various aspects of the scientific process, as well as the ability to apply scientific knowledge and processes in real situations faced by students, both as individuals, members of society, and citizens of the world.

This definition was further developed by Olsen and operationalized through three main dimensions that must include items: (a). The content dimension that identifies several areas in science is seen as a very relevant overall definition. (b). The competency dimension that identifies three scientific competencies: (1). Describing, explaining and predicting scientific phenomena; (2). Understanding scientific investigations; (3). Interpreting scientific evidence and the main conclusions of these competencies involve understanding scientific concepts, while the second and third can be relabeled as understanding the scientific process. The weight of the third competency item is 50% on competency 1 and 50% on competencies 2 and 3. (c). The situation dimension identifies three main contexts or areas of application; “Life and Health”, “Earth and Environment”, and “Science in Technology”.

Chabalengula *et al*. [61] stated that scientific literacy includes 4 aspects, namely: (a). knowledge of science; (b). the nature of scientific investigation; (c). science as a way of knowing; and (d). the interaction of science, technology and society. According to Toharudin *et al.* [62], scientific literacy is identified into six components, namely: (a). basic concepts of science; (b). nature of science; (c). work ethics of scientists; (d). the relationship between science and society; (e). the relationship between science and the humanities; and (f). understanding the relationship and differences between science and technology. PISA defines scientific literacy with characteristics consisting of four interrelated aspects, namely context, knowledge, competence, and attitude.

III. Materials and Methods

A. Research Design

This research is a type of quasi-experimental research. The research design used in this study is a non-equivalent control group design [63]. Where in this design, the experimental classes were given a pretest before carrying out learning which aims to determine the initial knowledge possessed by students in modern physics material. After being given treatment in the form of learning using integrated smartphone project-based learning media, a post-test was then carried out.

B. Population and Sample

The population in this study were all physics education students of Mataram University who were taking the modern physics course. The sampling technique used purposive sampling, which is a sample determination technique with certain considerations, namely the class used is taking the Modern Physics course in the third semester taught by the researcher. The sample in this study consisted of two classes, namely class A as the experimental class (25 people) and class B as the control class (25 people). The experimental class was taught with modern physics learning media based on integrated smartphone PjBL, while the control class was taught with the conventional models.

To minimize the bias that occurs in the research sample, especially the experimental class taught with a project-based model using smartphones, all indicators other than the model are made the same as the material taught, the teacher who teaches in class, the allocation of learning time, the number of students in the study, and, of course, the data instruments used. Some of these things certainly provide a small chance of bias in research, especially related to the influence of the application of the learning model in this study [64–66].

As for previous, which states that the application of the model in one of the classes called the experimental class or trial class, using PjBL using smartphones, is, of course, an approach that prioritizes students to solve problems that are actually encountered in the field [67]. In this learning, students will play the role of a professional who tries to solve problems in everyday life. The differences between the two classes will be visible because both classes will carry out the learning process in different ways. In the experimental class, the lecturer who teaches will give students the freedom to explore learning using a smartphone-based model. So students will get more experience, which will provide a strong memory for the final results. Meanwhile, in conventional learning, the class still uses teaching intermediaries or lecturers to obtain learning material, so it tends to be more passive and has an impact on students’ final results [68].

C. Research Instruments

In educational research, the common data collection technique is using instruments. In carrying out research, data is the main objective to be collected using instruments. The research instrument is the breath of the research. According to Nurfillaili and Anggereni [69], research instruments are tools chosen and used by researchers in carrying out activities to collect data so that these activities become systematic and made easier by them. Understanding research instruments from several experts:

1) Sugiyono [70] states that research instruments are used to measure the value of the variables to be studied.
2) Riduwan [71] believes that research instruments are tools that help researchers in collecting data; the quality of the instrument will determine the quality of the data collected, so it is correct to say that the relationship between instruments and data is the heart of research, which is interrelated.

From these various opinions, it can be concluded that research instruments are tools used to collect research data so that the data is easier to process and produces quality research. Data that has been collected using instruments will be described, attached, or used to test the hypothesis proposed in a study.

The instruments used in this study consisted of an essay test to measure creative thinking skills consisting of 10 questions that were adjusted to the creativity indicators, namely fluency thinking, flexible thinking, and original thinking. In addition, to measure scientific literacy, a multiple-choice test consisting of 20 questions was used that were adjusted to the PISA indicators in the reference [72], namely: covering science content, science processes and science contexts.

The characteristics or traits related to good research instruments include the following [73]:

1) Valid and reliable.
2) Based on a conceptual framework, or the researcher’s understanding of how certain variables in the research relate to each other.
3) Must collect data that is appropriate and relevant to the research topic.
4) Able to test hypotheses and/or answers to proposed research questions.
5) Free of bias and appropriate to the context, culture and diversity of the research location.

6) Contains clear and definite instructions for using the instrument.

D. Data Analysis Techniques

The data obtained in this study were then measured for improvement using the N-Gain test using Eq. (1) [74]. The results of the N-gain calculation obtained were matched with the N-Gain table. The N-Gain value consists of high categories (N-gain > 0.7), medium (0.70 > N-gain ≥ 0.30), and low (N-gain < 0.3) [75].

$$N - gain = \frac{s_{post} - s_{pre}}{s_{max} - s_{pre}} \quad (1)$$

where S_{post} is the post test score obtained, S_{pre} is the pre test score and S_{max} is the maximum score or ideal score.

Furthermore, to determine the effect of using modern physics learning media based on project-based learning integrated with smartphones, the data in this study were analyzed using inferential statistical tests using the t-test at a significance level of 0.05 with the condition that the data is normally distributed and homogeneous. The data normality test uses the Chi-square test, while the homogeneity test uses the F-test.

1) Use of Chi-Square: The Chi-Square test is useful for testing the relationship or influence of two nominal variables and measuring the strength of the relationship between one variable and another nominal variable (C = Coefficient of contingency) [76].
2) Chi-Square Characteristics
a) Chi-Square values are always positive.
b) There are several families of Chi-Square distributions, namely Chi-Square distributions with DK = 1, 2, 3, etc.
c) The shape of the Chi-Square Distribution is positive sticking out.

IV. Result and Discussion

This study aims to determine the increase in students' creativity and scientific literacy abilities by using modern physics learning media based on integrated smartphone project-based learning. The data generated in this study are in the form of students' creativity and scientific literacy abilities in modern physics learning. Data on students' creativity and scientific literacy were obtained through test instruments given before and after the learning process took place. The assessment of students' creativity abilities that were assessed was divided into three aspects of fluency, flexibility and originality. Meanwhile, for students' scientific literacy, three aspects were assessed based on PISA 2018, namely: including science content, science processes and science contexts [77–79]. The data on the results of students' creativity and scientific literacy are shown in Tables 1 and 2.

Table 1. N-gain values of creativity and scientific literacy in each sub-material

Sub Material	Creativity				Scientific literacy			
	Average value		N-gain	Category	Average value		N-gain	Category
	Pretest	Posttest			Pretest	Posttest		
Special theory of relativity	41.50	78.88	0.64	Moderate	40.55	76.58	0.61	Moderate
Quantum phenomena	44.74	88.55	0.79	High	49.70	78.50	0.57	Moderate
Matter waves	50.25	89.65	0.79	High	42.55	79.50	0.64	Moderate
Rutherford and Bohr model	50.45	87.75	0.75	High	49.90	77.75	0.56	Moderate
Quantum theory of the hydrogen atom	51.45	85.55	0.71	High	42.15	80.55	0.66	Moderate
Statistical Mechanics	46.59	89.70	0.81	High	44.30	79.75	0.64	Moderate
Atomic Nucleus	46.60	84.85	0.72	High	45.30	84.45	0.72	High
Radioactivity and nuclear reactions	51.25	85.76	0.71	High	48.15	85.20	0.71	High

Based on Table 1, it is known that the results of the N-gain analysis of the experimental class on the aspect of student creativity ranged from 0.64–0.81. As for the Special theory of relativity material, it has a score range of 0.70 > N-gain ≥ 0.30. This means that in this material students have an increase in creative thinking skills with a moderate category. As for the material Quantum phenomena, Matter waves, Rutherford and Bohr model, Quantum theory of the hydrogen atom, Statistical Mechanics, Atomic Nucleus, and Radioactivity and nuclear reactions, the N-gain score range is > 0.7. This means that in both sub-materials students have an increase in understanding of scientific literacy with a high category.

Based on Table 1, it is known that the results of the N-gain analysis in the experimental class on the aspect of scientific literacy skills ranged from 0.61 to 0.71. As for the material Special theory of relativity, Quantum phenomena, Matter waves, Rutherford and Bohr model, Quantum theory of the hydrogen atom, and Statistical Mechanics has a score range of 0.70 > N-gain ≥ 0.30. This means that in the six sub-materials, students have an increase in understanding of scientific literacy with a moderate category. As for the material Atomic Nucleus, Radioactivity and nuclear reactions has a score range of N-gain > 0.7. This means that in both sub-materials, students have an increase in understanding of scientific literacy with a high category.

Table 2. N-gain values for each indicator of creativity and scientific literacy

Indicator	Average value		N-gain	Category
	Pretest	Posttest		
Creativity				
Fluency	42.72	85.55	0.75	High
Flexibility	50.20	85.95	0.72	High
Originality	53.80	86.65	0.71	High
Scientific Literacy				
Science content	41.70	84.45	0.73	High
Science process	43.21	85.60	0.75	High
Science context	45.55	88.35	0.79	High

Based on Table 2, it is known that the results of the N-Gain analysis for students' creativity and scientific literacy have a range of N-gain scores > 0.7. This means that in the experimental class, students' creative thinking skills and scientific literacy are in the high category. This proves that the treatment given to the experimental class taught using the smartphone-based project-based learning model is more effective in increasing students' creativity and scientific literacy than the treatment given to the control class taught using the conventional model.

Furthermore, to determine the differences in the levels of creativity and scientific literacy of students in the experimental and control classes, a test of the difference in two means (t-test) was carried out which previously carried out prerequisite tests, namely normality and homogeneity tests. The normality and homogeneity values can be shown in Tables 3, 4, 5 and 6.

Table 3. Normality values for each sub-material in the aspects of creativity and scientific literacy

Sub Material	Group	N	Creativity				Scientific literacy			
			Average value	χ^2 count	χ^2 table (α = 0.05)	Criteria	Average value	χ^2 count	χ^2 table (α = 0.05)	Criteria
Special theory of relativity	Experiment	25	78.88	10.75	12.59	Normal	76.58	10.12	11.07	Normal
	Control	25	71.55	10.58			70.52	6.57		
Quantum phenomena	Experiment	25	88.55	9.20	9.48	Normal	78.50	8.70	11.07	Normal
	Control	25	72.65	8.50			72.50	7.65		
Matter waves	Experiment	25	89.65	8.20	11.07	Normal	79.50	11.41	12.59	Normal
	Control	25	70.52	10.77			74.50	10.58		
Rutherford and Bohr model	Experiment	25	87.75	7.76	9.48	Normal	77.75	5.56	9.48	Normal
	Control	25	70.50	8.58			70.52	7.79		
Quantum theory of the hydrogen atom	Experiment	25	85.55	5.98	11.07	Normal	80.55	8.98	9.48	Normal
	Control	25	71.25	9.36			73.25	7.80		
Statistical Mechanics	Experiment	25	89.70	10.22	12.59	Normal	79.75	11.62	12.59	Normal
	Control	25	73.55	11.56			74.55	9.80		
Atomic Nucleus	Experiment	25	84.85	10.56	11.07	Normal	84.45	11.03	11.07	Normal
	Control	25	74.55	10.90			74.60	9.60		
Radioactivity and nuclear reactions	Experiment	25	85.76	8.21	9.48	Normal	85.20	10.71	11.07	Normal
	Control	25	73.95	8.96			74.90	9.58		

Table 4. Normality values for each indicator of creativity and scientific literacy

Indicator	Group	N	Average value	χ^2 count	χ^2 table (α = 0.05)	Criteria
Creativity						
Fluency	Experiment	25	85.55	9.26	9.48	Normal
	Control	25	73.85	8.58		
Flexibility	Experiment	25	85.95	8.31	9.48	Normal
	Control	25	73.85	9.23		
Originality	Experiment	25	86.65	9.58	11.07	Normal
	Control	25	72.88	10.87		
Scientific Literacy						
Science content	Experiment	25	84.45	10.36	11.07	Normal
	Control	25	74.95	10.57		
Science process	Experiment	25	85.60	8.31	9.48	Normal
	Control	25	74.54	9.07		
Science context	Experiment	25	88.35	10.59	11.07	Normal
	Control	25	71.55	10.80		

Based on the normality and homogeneity values shown in Tables 3, 4, 5 and 6, it can be seen that the data obtained are normally distributed and homogeneous, so it can be seen that the type of t-test used is the polled variance t-test. The t-test values for each modern physics material and each indicator of creativity and scientific literacy are shown in Tables 7 and 8.

Table 5. Homogeneity value of each sub-material in the aspects of creativity and scientific literacy

Sub Material	Group	N	Creativity				Scientific literacy			
			Varians	F_{count}	F_{table} (α = 0.05)	Criteria	Varians	F_{count}	F_{table} (α = 0.05)	Criteria
Special theory of relativity	Experiment	25	188.65	1.54	1.98	Homogeneous	183.62	1.63	1.98	Homogeneous
	Control	25	122.35				112.29			
Quantum phenomena	Experiment	25	175.69	1.08	1.98	Homogeneous	177.89	1.07	1.98	Homogeneous
	Control	25	189.86				189.86			
Matter waves	Experiment	25	267.77	1.48	1.98	Homogeneous	256.87	1.61	1.98	Homogeneous
	Control	25	180.56				159.56			
Rutherford and Bohr model	Experiment	25	186.56	1.32	1.98	Homogeneous	176.56	1.41	1.98	Homogeneous
	Control	25	246.55				248.55			
Quantum theory of the hydrogen atom	Experiment	25	276.96	1.86	1.98	Homogeneous	146.77	1.75	1.98	Homogeneous
	Control	25	148.77				256.97			
Statistical mechanics	Experiment	25	169.59	1.58	1.98	Homogeneous	278.85	1.66	1.98	Homogeneous
	Control	25	267.85				167.59			
Atomic nucleus	Experiment	25	289.97	1.61	1.98	Homogeneous	159.65	1.79	1.98	Homogeneous
	Control	25	179.65				285.87			
Radioactivity and nuclear reactions	Experiment	25	187.87	1.54	1.98	Homogeneous	287.56	1.71	1.98	Homogeneous
	Control	25	288.86				167.99			

Table 6. Homogeneity values for each indicator of creativity and scientific literacy

Indicator	Group	N	Varians	F_{count}	F_{table} (α = 0.05)	Criteria
Creativity						
Fluency	Experiment	25	286.55	1.62	1.98	Homogeneous
	Control	25	176.56			
Flexibility	Experiment	25	158.87	1.77	1.98	Homogeneous
	Control	25	280.87			
Originality	Experiment	25	278.95	1.55	1.98	Homogeneous
	Control	25	179.89			
Scientific literacy						
Science content	Experiment	25	259.68	1.39	1.98	Homogeneous
	Control	25	186.38			
Science process	Experiment	25	165.79	1.75	1.98	Homogeneous
	Control	25	289.36			
Science context	Experiment	25	268.75	1.42	1.98	Homogeneous
	Control	25	188.66			

Table 7. Results of the t-test for each sub-material on the aspects of creativity and scientific literacy

Aspect	Sub Material	Group	N	Average value	Varians	t_{count}	t_{table} (α = 0.05)	Description
Creativity	Special theory of relativity	Experiment	25	78.88	188.65	3.63	1.67	Significant
		Control	25	71.55	122.35			
	Quantum phenomena	Experiment	25	88.55	175.69	5.63	1.67	Significant
		Control	25	72.65	189.86			
	Matter waves	Experiment	25	89.65	267.77	4.96	1.67	Significant
		Control	25	70.52	180.56			
	Rutherford and Bohr model	Experiment	25	87.75	186.56	3.76	1.67	Significant
		Control	25	70.50	246.55			
	Quantum theory of the hydrogen atom	Experiment	25	85.55	276.96	6.77	1.67	Significant
		Control	25	71.25	148.77			
	Statistical mechanics	Experiment	25	89.70	169.59	5.78	1.67	Significant
		Control	25	73.55	267.85			
	Atomic nucleus	Experiment	25	84.85	289.97	6.76	1.67	Significant
		Control	25	74.55	179.65			
	Radioactivity and nuclear reactions	Experiment	25	85.76	187.87	5.87	1.67	Significant
		Control	25	73.95	288.86			
Scientific literacy	Special theory of relativity	Experiment	25	76.58	183.62	4.59	1.67	Significant
		Control	25	70.52	112.29			
	Quantum phenomena	Experiment	25	78.50	177.89	3.92	1.67	Significant
		Control	25	72.50	189.86			
	Matter waves	Experiment	25	79.50	256.87	5.93	1.67	Significant
		Control	25	74.50	159.56			
	Rutherford and Bohr model	Experiment	25	77.75	176.56	4.56	1.67	Significant
		Control	25	70.52	248.55			
	Quantum theory of the hydrogen atom	Experiment	25	80.55	146.77	2.98	1.67	Significant
		Control	25	73.25	256.97			
	Statistical mechanics	Experiment	25	79.75	278.85	4.62	1.67	Significant
		Control	25	74.55	167.59			
	Atomic nucleus	Experiment	25	84.45	159.65	4.59	1.67	Significant
		Control	25	74.60	285.87			
	Radioactivity and nuclear reactions	Experiment	25	85.20	287.56	4.26	1.67	Significant
		Control	25	74.90	167.99			

Table 8. Results of the t-test for each indicator of creativity and scientific literacy

Indicator	Group	N	Average value	Varians	t_{count}	t_{table} (α = 0.05)	Description
Creativity							
Fluency	Experiment	25	85.55	286.55	5.53	1.67	Significant
	Control	25	73.85	176.56			
Flexibility	Experiment	25	85.95	158.87	4.87	1.67	Significant
	Control	25	73.85	280.87			
Originality	Experiment	25	86.65	278.95	2.54	1.67	Significant
	Control	25	72.88	179.89			
Scientific Literacy							
Science content	Experiment	25	84.45	259.68	2.01	1.67	Significant
	Control	25	74.95	186.38			
Science process	Experiment	25	85.6	165.79	3.83	1.67	Significant
	Control	25	74.54	289.36			
Science context	Experiment	25	88.35	268.75	3.43	1.67	Significant
	Control	25	71.55	188.66			

Based on Tables 7 and 8, it is clear that the value of the t-table is smaller than the t-count. This means that the use of modern physics learning media based on integrated smartphone project-based learning has a significant effect on increasing students' creativity and scientific literacy skills, especially in modern physics learning. This also means that the use of these media is more effective in increasing students' creativity and scientific literacy.

The findings obtained, for example, as shown in Table 1, when in the special theory of relativity material, the increase is categorized as moderate in the creativity aspect, then the scientific literacy aspect will also be categorized as moderate. In Table 2, when the increase in each creativity indicator is high, then the literacy ability is also high. This indicates that if students already have good scientific literacy skills, then it is likely that the students' creative thinking skills are also at a good level.

The creative thinking ability and scientific literacy of students in the experimental class which were higher than those in the control class were also triggered by several factors, one of which was a pleasant learning atmosphere [80, 81]. During the learning process, students seemed very enthusiastic in following the lesson because learning with modern physics learning media based on smartphone-integrated PjBL is student-centered learning and has several advantages including making it easier for students to learn the material, increasing motivation, training cooperation, responsibility and attracting students' attention. In addition, the advantage of this learning media is that it does not require an internet connection to run the application.

In the implementation of modern physics learning, teachers do not only provide material, but also involve students in problem-solving activities in groups, organize project activities, and produce real products [37]. The creative thinking skills and scientific literacy of students in the experimental class are higher than in the control class because in the experimental class students are given more opportunities to interact directly with the surrounding environment and develop their ideas in the form of group project work [82]. Student involvement in these activities allows students to apply their scientific concepts in real life, thus encouraging students' scientific literacy skills to develop better than those who do not receive project learning [83]. In addition, the quality of the teaching materials used by teachers plays an important role in providing learning experiences that contain scientific literacy. This is what causes students who are taught with modern physics learning media based on smartphone-integrated PjBL to have higher scientific literacy scores compared to students who are taught with conventional models [84–86].

In implementing research using a smartphone-assisted project-based learning model, of course there are several challenges that researchers find, namely the need for good schedule management because this learning model requires students to be able to work within a certain period of time so that without good planning at the beginning, it is possible that at the next meeting in each phase of learning various obstacles will be found. In addition to referring to the schedule or implementation time factor, future researchers also need to consider the human resources that are the target of the research, because this model is more dominant, students will learn independently with their respective group members, so researchers need to ensure that in the group there are students who have more abilities in the topic that is the center of research, especially if using learning media [87].

This is in line with the opinion that learning using PjBL is learning through context, visualization, and collaboration and is able to accommodate students with different cognitive abilities [88]. With the help of smartphones, it will be easier for students in the learning process both in class and outside of class. With the development of technological advances, many innovations can be born, one of which is in the learning process [89]. With the help of smartphones, the learning process can be carried out by developing knowledge and making the learning process easier, not just confined to the classroom. As time goes by, technology is developing so that cognitive abilities can not only be obtained from teachers, but with smartphones, students can open several offline applications such as e-books or e-modules as learning materials used in independent learning arranged systematically in learning units [90].

Based on the results of the study using the smartphone-assisted PjBL model reviewed to improve creativity and scientific literacy of physics, it has met the procedures according to Samsu *et al*. [91]. The results obtained are that there is an increase in student creativity and literacy when using a project-based learning model with sophisticated technology, namely using a smartphone. This happens because the learning model used in the learning process tends to still use conventional methods with lectures so that students only focus on paying attention and understanding the explanations given by the teacher. A change in the learning model is needed [92]. One of the learning models that supports students to improve their creativity and scientific literacy of physics is the PjBL learning model assisted by smartphones.

V. Conclusion

Based on the results of the study, it can be concluded that the use of modern physics learning media based on smartphone-integrated project-based learning can improve students' creativity and scientific literacy. This is indicated by the value of increasing creativity and scientific literacy having medium and high categories. In addition, the t-table value < t-count. This means that the use of media with a smartphone-based PjBL model has a significant effect on increasing students' creativity and scientific literacy, especially in modern physics learning, and the use of this media has proven effective in the learning process because it makes it easier for students to learn the material, increases motivation, trains cooperation and responsibility, and attracts students' attention. In addition, the advantage of this learning media is that it does not require an internet connection to run the application. so that it allows students to develop e-books as learning materials that can be used by other students. students' creative thinking skills and scientific literacy.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

S drafted the research framework, conducted the research, and wrote the paper; AD conducted the research and analyzed the data; JR conducted the research and analyzed the data; LM, DRR, ZF, MI, and NRA conducted the research; all authors had approved the final version.

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