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Fostering Scientific Creativity Through Feasibility Project-Based Learning in Undergraduate Physics

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ABSTRACT Education plays a crucial role in building human resources. In the 21st century, a person is required to master four skills, one of which is creativity, as a response to the increasingly rapid development of technology towards a society 5.0. The development of a PjBL model combined with scientific creativity represents the innovation in this research. This study aims to enhance students' scientific creativity in introductory Physics 1 courses through a scientifically creative project-based learning model, which has been further developed and evaluated for its validity, practicality, and effectiveness. This research method is a developmental research process that comprises four phases: preliminary, development, validation, and implementation. The sample for this study consisted of 175 students. The practicality and efficacy of this study are assessed using student response questionnaires, test instruments, and implementation observation guidelines. Research findings: 1) validity, the validity results show that the research tools are valid and reliable; 2) practical, well implemented, and can be used for the learning process; 3) effective, can significantly improve the scientific creativity of undergraduate students at $\alpha = 5\%$, The typical n-Gain of learners falls within the high range, and the feedback from students regarding the learning experience is highly favorable. This study concludes that the SCPjBL model is an effective method for enhancing the scientific creativity of college students enrolled in introductory physics classes.

Keywords: Feasibility, Scientific creativity, Project-based learning, Learning, Physics learning

1. INTRODUCTION

The role of universities is not only to prepare individuals to master broad knowledge and insight. However, universities play a crucial role in preparing a generation that can compete and innovate in the current era of the Industrial Revolution 4.0 towards 5.0 (Andres & Rosalinda, 2023; Rahayu et al., 2022). Universities must be able to prepare prospective teachers who possess a range of skills relevant to their respective fields. To support the achievement of these skills, prospective physics teacher students must prepare the things that are currently needed, such as Critical thinking skills, problem-solving, creativity, innovation, collaboration, and communication (Wibowo, 2023) and skills needed for the future, such as digital skills (Shofiyah et al., 2025), adaptable skills (Admoko et al., 2023). Creativity emphasizes the skills to produce original ideas. In the realm of science, this concept is referred to as scientific creativity. (Hu & Adey, 2010; Mukhopadhyay & Sen, 2013). Scientific creativity optimizes high-level thinking skills to produce new, unique, and valuable ideas (Suyidno et al., 2020). Developing complex thinking skills is one of the primary goals of 21st-century education (Sumo et al., 2024). One of the characteristics of someone with scientific creativity is the use of unusual ideas, technical improvements in product quality, solving complex problems, and producing innovative and valuable products (Siew & Ambo, 2020). Scientific creativity can be measured by the achievement of scientific creativity indicators consisting of several leading indicators, namely: being able to identify scientific phenomena, develop scientific knowledge, solve scientific problems, improve product quality technically, be able to think scientifically and be able to design creative products that meet aspects of creative personality (Hu & Adey, 2002; Nur et al., 2018).

In reality, higher education is still not fully able to optimize 21st-century skills, one of which is creativity; this

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is based on the results of a study conducted by (Georgiou et al., 2022) in Australia in physics courses where physics class students are still not fully able to master scientific creativity, especially in the creative imagination indicator, where they get a score below other scientific creativity indicators, namely 7 out of a maximum score of 20. This fact is not limited to Australia but also applies to Indonesia, where the scientific creativity score of students in the physics education study program remains relatively low, with an average score of 1.5 out of a maximum score of 4.0 (Sumo et al., 2024). This problem needs to be resolved immediately, considering that students in higher education, especially those studying physics, are prospective physics or science teachers who will later become educators in certain educational institutions. Teachers who utilize various skills they possess will help students develop their skills, especially high-level thinking skills. This is important because, based on the findings of PISA, the abilities of Indonesian students, especially in the field of science, remain in the low category; only 10% of students possess high-level thinking skills (PISA, 2023). The student can think at level two, namely understanding the problem, while creativity requires level six abilities, namely being able to create.

To overcome the above problems, a strategy is needed, including improving the learning process in higher education, one of which is implementing a learning model that can improve students' scientific creativity, especially in the field of physics courses; this is important because the learning process is the spirit in delivering learning materials to students where the learning model cannot be separated from the learning steps that lead to the success of the learning process (Aero, 2023; Arends, 2008). Several learning models have been employed to enhance student creativity, one of which is the project-based learning model.

This project-based learning model has several advantages over other learning models; among these advantages is that it can enhance collaboration and creativity (Ariandani et al., 2020; Setemen et al., 2023). From these advantages, many countries have incorporated it into their curriculum systems, and some also utilize it as a learning approach. The countries that have included this learning model in their education curricula include: 1) the United States. America has included a project-based learning model since the 1900s. The results show that, with the project-based learning model, collaboration and creativity can be increased in the long term (Boss, 2011). 2) China has integrated the project-based learning model into its elementary education curriculum and implemented it in several schools since the reform era began in 2005 as a form of innovative education. The results of implementing this model demonstrate that students can think creatively, even in the early stages of development (Hu, 2024). 3) Germany Germany has implemented the project learning model in the vocational education system since 1990. The results of implementing this model are helping students to be better prepared to face the world of work (Tadros et al., 2019). 4) In Finland, the project-based learning model, combined with phenomena-based learning, was officially implemented in 2016. The results of integrating the PjBL model have a positive impact, specifically that students can improve in terms of activeness, collaboration, and creativity (Schaffar & Wolff, 2024). 5) Indonesia the Republic of Indonesia has started to include it in the elementary and secondary school curriculum since 2013. The results of implementing the PjBL model can increase students' creativity and critical thinking skills, especially in the field of science Oktavia et al., 2023).

Scientific creativity is a type of science learning that emphasizes students' ability to produce unique, original, and scientific ideas, resulting in innovative products in the form of ideas or tangible goods (Hu & Adey, 2010). This is reinforced by cognitive learning theory, which states that scientific investigation tasks will be more effective if students are prepared in advance (Moreno, 2010). The integration of prior knowledge with current learning experiences is a crucial asset in implementing meaningful learning (Slavin, 2016). This is also reinforced by the research results of Cirkony (2023), Guasch et al. (2020), Sumo et al. (2024), and Putri et al. (2019), which state that prior knowledge serves as the initial foundation in scientific investigation-based learning. In addition to initial knowledge, guiding or training thinking skills also plays an important role in students' learning success (Altiparmak & Eryilmaz-Muştu, 2021; Ananda et al., 2023). The SCPjBL model integrated with scientific creativity has six phases, namely: (1) starting with a science phenomenon, (2) planning project tasks, (3) exploring knowledge, (4) designing and planning project tasks, (5) monitoring the completion of project tasks, and (6) evaluating learning experiences.

The Project-Based Learning (PjBL) model is rooted in the progressive approach to education introduced by John Dewey in the early 20th century. Dewey emphasized the importance of direct experience and active student involvement in the learning process through real-world projects relevant to their lives (Boss, 2011). In the context of physics learning, PjBL was developed because it enables the integration of abstract concepts with more meaningful real-world applications (Khoiri et al., 2023). With PjBL, students not only understand physics concepts theoretically but also apply them in real-life contexts through experiments, tool-making, or project-based problem-solving (Kartika et al., 2019).

The PjBL model, integrated with scientific creativity, has been proven to be feasible in improving students' scientific creativity in physics courses (Dwikoranto et al., 2021). However, there are still shortcomings that need to be addressed, specifically in the first phase, which involves essential questions, the second phase of planning project assignments, and the product design phase. The solution proposed in this study is to integrate indicators of scientific creativity into understanding scientific phenomena, starting with the first phase so that the first phase begins with an understanding of scientific phenomena. The second solution integrates scientific knowledge (Scientific Knowledge) into the third phase, namely the exploration of scientific knowledge (Scientific exploration), and the third solution is to design and design creative project assignments; in this phase, the researcher includes indicators of creative personality assisted by creative thinking techniques (Scamper and Listening Attributes). The results of other studies indicate that integrating scientific creativity with problem-solving-based learning models has proven effective (Zulkarnaen et al., 2017; Suyidno et al., 2017).

According to the earlier research explanation, a gap remains in the project-based learning model's effectiveness in addressing issues related to 21st-century competencies, particularly in scientific creativity. Consequently, this study aims to enhance the PjBL model to solve these challenges. The novelty of this research lies in the integration of PjBL models with a scientific creativity approach, which is carried out on the syntax of the Project-based Learning model and the overall scientific creativity indicators. The urgency of developing this model lies in meeting the need for an effective learning model that improves 21st-century skills. The contribution of this research is to introduce a new theory that a PjBL model, developed using a scientific creativity approach, can enhance 21st-century skills in college students. This contribution will add to the knowledge base in the field of pedagogy.

1.1 Theoretical Background

Scientific Creativity in Physics Learning

In physics, creativity is referred to as scientific creativity (Mukhopadhyay, 2013). An individual's capacity to generate novel ideas that are both unique and valuable to a large number of people within the scientific context is what defines scientific creativity. (Ayas & Sak, 2018). Scientific creativity shares similarities with creativity in general, but it also exhibits distinct differences. Scientific creativity is a special form of general creativity in the context of science. Guilford was the first figure to develop the concept of divergent thinking as the core of general creativity, which was later referred to as scientific creativity in the field of science, emphasizing the aspects of fluency, flexibility, originality, and elaboration. Torrance developed scientific creativity by administering the Torrance Tests of Creative Thinking (TTCT), which emphasizes the aspects of fluency, flexibility, and originality (Hu & Adey, 2002).

There are seven indicators of scientific creativity, namely scientific knowledge, scientific phenomena, scientific problems, technical products, scientific thinking, scientific design products, and scientific problem solving (Hu & Adey, 2010; Torrance, 1965). These indicators of scientific creativity are interrelated. Scientific creativity in physics learning is built upon several theories, including Moreno's cognitive learning theory (2010), Slavin's constructivist learning theory (2016), and Bruner's theory of meaningful learning. These theories suggest that activating cognitive abilities and skills together can be achieved by providing real-world stimuli.

Project-Based Learning Model

Project-based learning is a learning model that reflects several learning theories, such as Vygotsky's social theory, which posits that learning occurs through social interactions that encourage individuals to face cognitive challenges that are only slightly above their current level of understanding. Students build knowledge as they attempt to understand their experiences in light of their previous abilities. Experience can occur when individuals are actively engaged in meaningful discussions and interactions with lecturers or peers who are more capable. As a result, students will experience meaningful learning through the process of exploration, interpretation, negotiation, and creation of products, namely presentations and written reports, which are necessary for their project work. In other words, learners are directly involved in building their understanding based on their individual experiences with the world around them. (Dolmans, 2019). The PjBL learning model has a syntax consisting of several phases, namely: (1) Starting learning with essential questions; (2) Planning project tasks; (3) Following the activity schedule; (4) Monitoring the progress of project tasks; (5) Assessing project results; (6) Evaluating learning experiences (Lucas, 2005).

The use of PjBL in higher education, for example, in introductory physics courses, is the most effective teaching option and contributes significantly to the development of basic competencies and curricular learning (Santyasa et al., 2020). This is because: (1) learning is based on problem formulation as a starting point in learning and places the process of asking questions more important than finding answers; (2) students' implicit experiences as part of the learning process that occurs and connecting problems with individual experiences can increase their learning motivation; (3) project tasks constitute a significant part of the learning process so they need to be completed through information searches and decision making; (4) students learn to connect empirical experiences with theories that have been learned; (5) group work is felt to be able to develop implicit personal competencies related to the management of the collaboration process (Kartika et al., 2019; Saepudin, 2020). In addition, the characteristics of PjBL are: (1) Complex problems or challenges are presented; (2) The process of designing problem-solving through investigation; (3) Students understand and apply the knowledge and skills they have in various project contexts; (4) Cooperation in cooperative teams and discussing the results; (5) Students practice various skills needed for their future lives and careers (allocating time, being a responsible individual, personal skills, learning through experience); (6) Students periodically reflect on the activities that have been carried out; (7) The final product of students in working on projects (Sulisworo, 2020).

2. METHOD

2.1 General Research Methods

This study was conducted for one year in two study programs at two universities located in Madura, East Java, in 2024. Both study programs share the same characteristics, namely that students in the two programs take introductory physics courses. Second, the semester level is the same. Third, their average age is not much different. Both study programs do not encounter difficulty generalizing the research findings because the sample size is quite large and representative of the research population (Sugiyono, 2018). This research aimed to evaluate the validity, practicality, and effectiveness of the SCPjBL model in enhancing the scientific creativity of undergraduate students studying Physics Education. The steps of the modified development research, as outlined by Plomp and Nieven, are illustrated in Figure 1. In the figure, this study begins with a preliminary stage, which involves a literature review and field study to gather information related to theories and facts in the field regarding students' scientific creativity. Then, it proceeded to the hypothesis formulation stage, which involved creating a hypothetical model. The hypothetical model, in the form of a draft and learning tools, will be reviewed by three validators from the State University of Surabaya and Trunojoyo University, Madura, East Java. The three validators are experts in the fields of learning models, physics education, and assessment and evaluation. The three validators review the aspects of the research instrument according to their respective areas of expertise. After the review is carried out and validation is conducted, the process proceeds to the model implementation stage once it is declared valid. The implementation of the SCPjBL research model involves conducting both limited trials and extensive trials to produce valid, practical, and effective products (Plomp & Nieveen, 2010).

2.2. Design of Research

This study employs a development research method adapted from Plomp & Nieveen (Akker et al., 2013). The steps of this study consist of three stages: a preliminary study, which begins with a literature review, and a field study. This preliminary study was conducted to investigate theoretically and empirically the concept of scientific creativity and the learning model that has been applied thus far. The second step involves developing a hypothetical model and assessing research instruments. This design aims to find an ideal model that overcomes the limitations of the previous model. The third step, namely the validation of the model and research tools, is done to find a valid and reliable model prototype. The final step is implementing the model in the field. This implementation is carried out in two stages: limited testing and extensive testing of the model. The latter is conducted to assess the model's feasibility, which is then reviewed for practicality and effectiveness. The design in this study is a one-group pre-test and post-test design. The choice of this type of research is due to the need to master 21st-century skills, specifically creativity and innovation, which not only hone

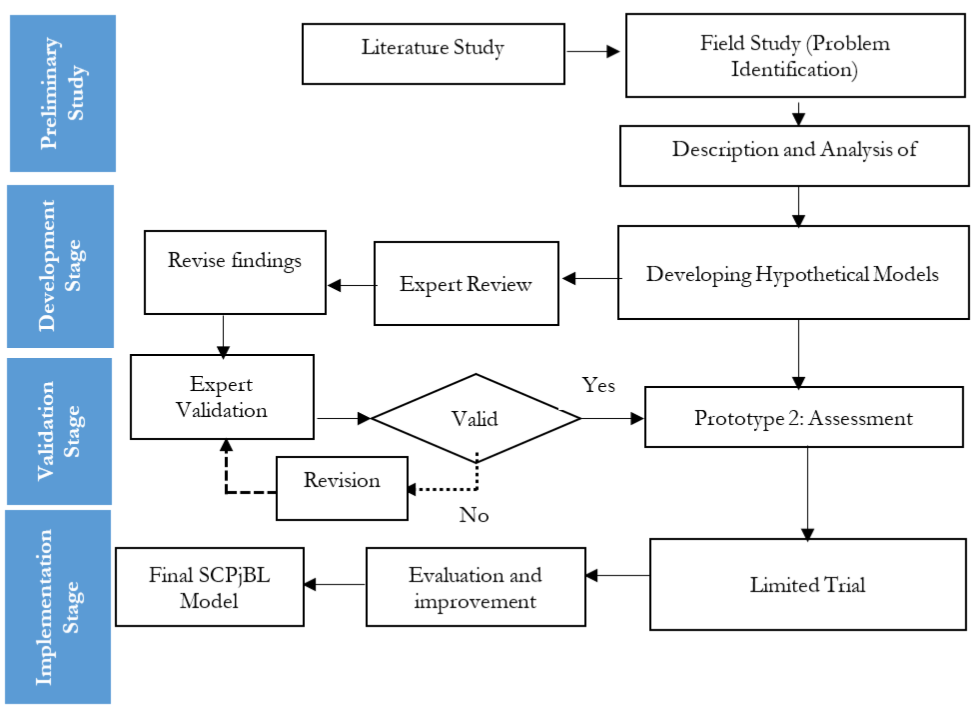


Figure 1 Flowchart of research and development of SCPjBL model

students' cognitive skills but also improve their skills through evidence of scientifically based, innovative products (Wainwright, 2018). With the one-group pre-test and post-test design, researchers can more directly control the research sample and focus on it (Creswell, 2018). The detailed research design is shown in Table 1.

Table 1 Research design

Group	Pre-test	Treatment	Post-test
One group pre-test post-test design	O_1	X	O_2

(Creswell & Creswell, 2018)
Information: O_1 : Pre-test ; O_2 : Post-test ; X : Treatment

2.3 Research Sample

The sample in this study consisted of 175 students from the physics education study program at the Islamic University of Madura and the natural science education study program at Trunojoyo University of Madura. The sample of this study was divided into two research trials; for more details, see Table 2.

Table 2 Sample of research

Trials of research	Study Program	
	Physics Education	Natural Science Education
Limited of trial	30	40
Extensive trial	45	60
Total	75	100

The research subjects from two academic programs, specifically the Physics Education Study Program at the Islamic University of Madura and the Natural Sciences Education Study Program at Trunojoyo University of Madura, share identical traits regarding their skill levels, current semester, and age. Thus, any variations observed during the study are directly tied to the SCPjBL learning framework. The selection of research samples is based on the Slovin formula (Sevilla, 1984) with an error tolerance of 5%.

$$\text{Sample} = \frac{N}{1 + N.e^2}$$

Information:
N: Population size
e: Percentage of error tolerance

2.4 Research Instruments

The research instrument in this study consists of validity measures based on the results of expert assessments. The reference for the validity of learning devices in this study is the Plomp & Nieveen (2010) scale. This validity assessment aims to evaluate the validity and reliability of the learning tools. The validation form employed to evaluate the research instruments and tools includes two dimensions: the construct dimension and the content dimension. The equation employed to determine the validity score is outlined below.

$$\text{Validity} = \frac{\text{score obtained}}{\text{Maximum Score}} \times 4$$

The scores obtained from the calculation results are then interpreted according to several criteria, including valid, very valid, less valid, and invalid. Details are presented in Table 3.

Table 3 Criteria for assessing the validity of the SCPjBL model

Assessment criteria	Information
Very valid	It can be used without revision
Valid	It can be used with minor revisions
Less of valid	It can be used with minor revisions
Not Invalid	It is not yet usable and requires consultation

From the outcomes of assessing the validity of the learning model, the next step is to compute the reliability of that model. The reliability calculation for the validation tool of the SCPjBL model and its educational resources is determined by the agreement between observers, as outlined by Borich (1974). The formula used for the percentage of agreement (R) analysis is presented below.

$$R = \left[1 - \frac{A-B}{A+B}\right] \times 100\%$$

Information:
R: Proportion of dependable tools
A: Evaluation of validators who provide elevated ratings
B: Evaluation of validators who provide low ratings.

After the reliability calculation is completed, it is then compared with Cronbach's Alpha. The research instrument is considered reliable if its reliability value is 75% or higher (Borich, 1974). The Cronbach's Alpha reliability criteria interval is shown in Table 4.

Table 4 Cronbach's alpha reliability interval

Cronbach's Alpha (α) interval	Assessment criteria
0.90 - 1	Very high
0.70 - 0.89	high
0.50 - 0.69	Currently
α < 0.49	Poor

(McMurray & Brownlow, 2014)

The feasibility assessment instrument consists of a validity sheet and an observation sheet for implementing the model syntax. For effectiveness, a test sheet and a student response questionnaire are used with assessment criteria as in Table 5.

Table 5 Criteria for assessing the implementation of the SCPjBL model

Score Interval	Assessment criteria
3.25 - 4.00	Very good
2.50 - 3.24	Good
1.75 - 2.49	Enough good
1.00 - 1.74	not good

(Prahani, 2023)

The practicality of learning outcomes with the SCPjBL model is categorized as good if the average score is ≥2.50 and is considered reliable if the average percentage score is ≥75% (Borich, 1974). The success of the Scientific creativity project-based learning model is evident from the rise in scientific creativity scores observed in the students' pre-test and post-test results, which were assessed through N-Gain analysis. The level of increase in scientific creativity is determined based on the initial test data and the final test results, and it is calculated using the n-gain equation (Hake, 1998) below.

$$\langle g \rangle = \frac{\langle S_f \rangle - \langle S_i \rangle}{max\ score - \langle S_i \rangle}$$

Information :
Sf: Highest value
Si: Lowest value
<g>: Gain Score

The data obtained from the gain test results are then interpreted into high, medium, and low criteria. For more details, see Table 6.

Table 6 N-gain criteria

N-gain value	Criteria
$g > 0.70$	High
$0.30 \leq g \leq 0.70$	Moderate
$g < 0.30$	Low

In addition to calculating the increase in creativity with tests, The success of the educational model is determined by how actively students engage with the learning experience. The instrument used to measure student responses is a response questionnaire. This student response questionnaire is designed to determine the effectiveness of learning devices and the teaching methods used by lecturers in conjunction with the SCPjBL learning model. The data from the student response questionnaire are calculated descriptively and qualitatively using the equation below.

$$P = \frac{\sum R}{\sum N} \text{ x } 100\%$$

Information:
P: Percentage,
R: Number of responses,
N: Total number

Student responses are considered good if each stage of the learning process achieves a score of 75% or higher. Student response data were analyzed using quantitative and qualitative descriptive methods (Astutik & Prahani, 2018; Prahani, 2023; Nur et al., 2018), with the criteria outlined in Table 7.

Table 7 Student response criteria for the SCPjBL model

Score	Criteria
Response ≥ 75%;	Very good
50% ≤ Response < 75%;	Good
25% ≤ Response < 50%	Poorly
Response < 25%	Not good

2.5 Data Analysis

In analyzing the data, this study employs several statistical procedures to determine the validity, practicality, and effectiveness of the SCPjBL learning model. However, prior to performing the parametric statistical test, a normality and homogeneity test is conducted to assess whether the data is normally distributed. The data are normally distributed at a 95% significance level, as indicated by the normality and homogeneity test results. The significance value (sig.) is used to determine whether the data are homogeneous for the homogeneity test. If $p > 0.05$, the data are deemed homogeneous; if $p < 0.05$, the data is considered inhomogeneous. Following the normality and homogeneity tests, a paired t-test is performed on the data to assess whether the implementation of the SCPjBL learning model results in an increase between the pre-test and post-test outcomes. The research hypothesis is formulated as follows.

H_0: There is no increase in students' scientific creativity before and after learning with the SCPjBL model.

H_1: There is an increase in students' scientific creativity before and after learning with the SCPjBL model

The basis for decision-making for the t-test is if p-value $<\alpha$, then H0 is rejected. If p-value $> \alpha$, then H0 is accepted with a significance level of 95%.

2.6 Procedure of Research

In this study, the application of the Scientific Creativity Project-Based Learning model utilizes seven syntaxes, namely: 1) starting with scientific phenomena. At this stage, students are required to identify problems related to physics and 2) plan project assignments. At this stage, students have searched for materials and tools to meet their experimental needs. 3) exploring knowledge. At this stage, students study physics related to scientific phenomena problems. 4) designing and planning project assignments. Students have written a project schedule. 5) monitoring project assignments. The lecturer checks the results of the physics project assignment planning. 6) assessing the results. At this stage, the lecturer provides an initial assessment related to the design of the project assignment, 7) evaluating the experience. The lecturer reflects on the project assignments they are working on. For more details, see Table 8.

Table 8 SCPjBL model syntax and learning activities

SCPjBL model syntax	Activity
Scientific Phenomenon	Observing scientific phenomena demonstrated by lecturers and noting down the physics concepts contained in scientific phenomena.
Planning a physics project assignment	Select a project topic and create a project completion progress schedule.
Exploration of scientific knowledge	Deepening the concept of physics
Designing and planning project tasks	design and create product assignments
Monitor project tasks	Assisting with project task progress
Assessing the results	Presenting design results
Evaluating experience	Provide an assessment of the products produced.

3. RESULT AND DISCUSSION

The findings of this research are presented in terms of the validity, practicality, and effectiveness of the educational model, as detailed below.

3.1 Validity of the SCPjBL Model

Before being applied in the learning process, the instrument must be valid and reliable. Three experts assessed the validity of the SCPjBL model research instrument. The results of the research and learning instrument assessment are presented in Table 9.

The findings regarding the validity of the model instrument and educational tools, as presented in Table 9, indicate that the average validity score is 3.93. This result exceeds the minimum validity achievement of 2.5, indicating a very valid category. While the results of the calculation of the percentage of understanding between validators reached 97%, this result exceeds the minimum reliability limit of 75%. Based on this information, it means that the SCPjBL model's learning instruments and devices are consistent in all components; this result aligns with the statement from Van den Akker et al. (2013), which states that effective learning devices meet valid and reliable criteria. The results of other studies also indicate that the design of instruments for assessing and evaluating scientific creativity can be used for valid and reliable purposes (Pont-Niclòs et al., 2023).

3.2 The practicality of the SCPjBL Model

The results of the analysis and calculation of scores at each learning phase using the SCPjBL model in both limited trials and extensive trials are shown in Table 10.

Table 10 displays the findings from the analysis of the feasibility data regarding the implementation of the SCPjBL learning model. The results of the practicality data analysis are calculated by calculating the average score (observation score) at each stage of the SCPjBL model implementation. Four observers observe each step of learning with the SCPjBL model. According to the findings from the analysis of practicality data, the SCPjBL model falls into the highly practical and dependable category. These results suggest that the role of lecturers is highly supportive of physics learning, particularly in fostering scientific creativity. Meanwhile, student activities using the SCPjBL model in Basic Physics Learning 1 are presented in Table 11.

Physics learning is carried out using the Scientific Creativity Project-Based Learning (SCPjBL) model, which consists of seven steps as follows: First, learning begins with an exploration of scientific phenomena. At this initial stage, students search for relevant physics material information and then collaborate in front of the class, as shown in Figures 2 and 3.

Based on the implementation of learning using the Scientific Creativity Project-Based Learning (SCPjBL) model, which consists of seven steps described as follows: first, learning begins with an exploration of scientific phenomena. In this phase, the implementation is excellent, as students are enthusiastic about listening to the scientific phenomena presented and actively responding to questions from lecturers. This indicates that lecturers can enhance student learning motivation by presenting scientific phenomena. This aligns with the statements of Moreno

Table 9 Findings on the SCPjBL model research instrument's validity and reliability

Components	The Validity of SCPjBL model instruments	
	Validity	Reliability
Semester learning plan	3.92: Valid	97%: Reliable
Lecture program unit	3.91: Valid	98%: Reliable
Student Book	3.88: Valid	97%: Reliable
Student worksheet	3.94: Valid	97%: Reliable
Scientific creativity test sheet	3.95: Valid	96%: Reliable
Practical Learning Observation Sheet	3.97: Valid	97%: Reliable
Student Response Questionnaire	3.96: Valid	98%: Reliable
Average	3.93: Valid	97%: Reliable

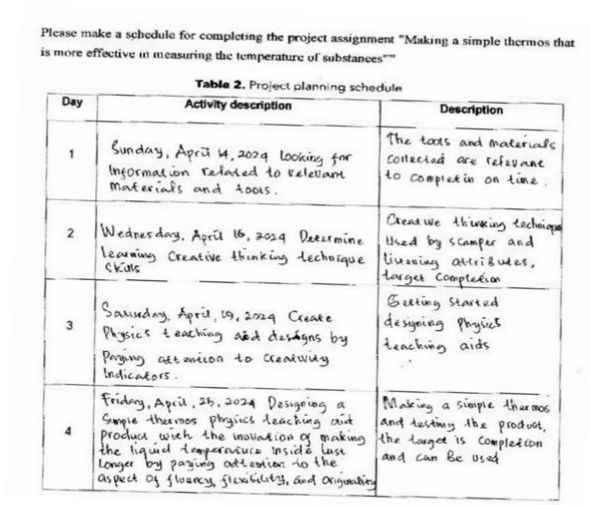
Table 10 The practicality of the SCPjBL model in limited trials and extensive trials

Syntax	Limited trials			Trials Extensive		
	Score	Category	Reliable	Score	Category	Reliable
Phase 1	3.73	Very good	Reliable	3.26	Very good	Reliable
Phase 2	3.58	Very good	Reliable	3.41	Very good	Reliable
Phase 3	3.78	Very good	Reliable	3.54	Very good	Reliable
Phase 4	3.48	Very good	Reliable	3.52	Very good	Reliable
Phase 5	3.79	Very good	Reliable	3.71	Very good	Reliable
Phase 6	3.54	Very good	Reliable	3.70	Very good	Reliable

Table 11 Student activities using the SCPjBL model

Student Activities
Phase 1: Starting learning with scientific phenomena
Students observe physiological phenomena, write down the physics concepts contained in scientific phenomena, and then listen to an explanation of the learning objectives and the importance of being a creative person.
Phase 2: Planning a physics project assignment
Students form groups and choose a project assignment topic, then create a schedule for completing the project assignment.
Phase 3: Knowledge Exploration
Each group of students explores knowledge related to the topic; the knowledge that has been studied is then presented with the results of exploring physics material.
Phase 4: Designing and planning physics project assignments
Designing and developing physics teaching aid products (Creative design ability) as a solution to solving science problems (Problem-solving) and fulfilling the aspects of fluency, flexibility, and originality through creative thinking steps (Creative thinking).
Phase 5: Monitoring the completion of physics project tasks
Managing time well in solving problems related to project tasks and optimizing thinking skills (Problem-solving and Creative thinking).
Phase 6-7: Assess the results and evaluate learning experiences
Students communicate the results of project task performance and solve science problems related to aspects of scientific creativity (problem-solving).

Figure 2 Students collaborating



Please make a schedule for completing the project assignment "Making a simple thermos that is more effective in measuring the temperature of substances""

Table 2. Project planning schedule

Day	Activity description	Description
1	Sunday, April 14, 2024 looking for Information related to relevant materials and tools.	The tools and materials collected are relevant to complete in on time.
2	Wednesday, April 16, 2024 Determine learning Creative thinking technique skills	Creative thinking technique used by scamper and listening attributes, target completion
3	Saturday, April, 19, 2024 Create Physics teaching aid designs by paying attention to creativity indicators.	Getting started designing Physics teaching aids
4	Friday, April, 25, 2024 Designing a simple thermos physics teaching aid product with the inovation of making the liquid temperature inside last longer by paying attention to the aspect of fluency, flexibility, and originality	Making a simple thermos and testing the product, the target is completion and can be used

Figure 3 Results of creating a task plan

(2010) and Slavin (2016), which suggest that lecturers should shift from extrinsic to intrinsic motivation by fostering high curiosity and enthusiasm. Creativity will emerge along with the rise of motivation in a person (Altiparmak & Eryilmaz-Muştu, 2021). Learning will be meaningful if the learners can connect their previous knowledge with a scientific phenomenon (Mukhopadhyay, 2013).

In the second phase, they plan project assignments; in this stage, students write a project work plan from start to finish, culminating in an innovative product. In this planning, students must pay attention to the completion time so that the project assignment is completed on time. The visualization of students when planning project assignments is shown in Figures 4 and 5.

Activities in Phase 2, as shown in Figure 2, students collaborate to form groups both in limited trials and extensive trials; in this phase, students are allowed to collaborate in groups to exchange ideas and concepts to produce a plan, as Figure 3, project assignment planning is focused on solving problems related to scientific phenomena. This planning is done as a team. The formation of diverse teams is rooted in the idea of collaborative learning; this collective learning aligns with Vygotsky's social constructivist theory, which emphasizes the importance of the social environment in knowledge development (Arends, 2008). Preparing a plan in order to solve problems will have a positive impact on subsequent scientific investigation activities (Dwikoranto et al., 2021). Students choose their project topics independently, which provides a democratic atmosphere (Coulter, 2020).

Phase 3 Exploration of scientific knowledge: In this phase, students are allowed to explore physics knowledge related to the project assignments they will work on; this exploration activity consists of deepening knowledge independently, searching for information related to the material, and then presenting in front of the class, the visualization of this activity is shown in Figure 4 and Figure 5.

Students explore knowledge by searching for information related to physics materials, including

Figure 4 Students explore physics material

Figure 5 Students presenting material

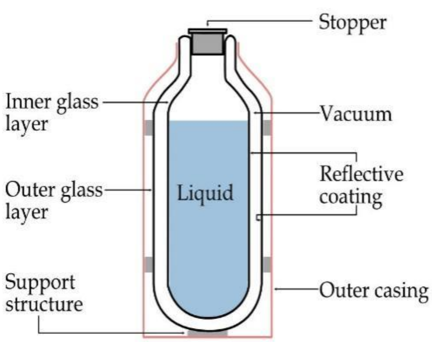


Figure 6 Conventional thermos design

concepts and laws of physics relevant to their project assignments. Afterward, they present their findings to the class, which are then tested for depth of knowledge by the lecturer. Students are accustomed to exploring physics concepts to provide scientific reasons when designing project assignments. This aligns with the theory of information processing, which suggests that students can retain knowledge stored in their brain memory for a long time (Slavin, 2016). Mastery of initial knowledge is more effective in the learning process (Rusmini et al., 2021; Sumo et al., 2024).

The fourth phase of the learning model involves designing and developing project assignments. In this phase, it was carried out very well because the lecturer provided guidance on preparing for the needs of scientific investigations. Additionally, the lecturer provided instructions on designing products that incorporated

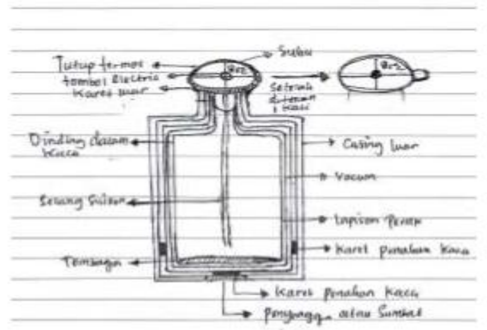
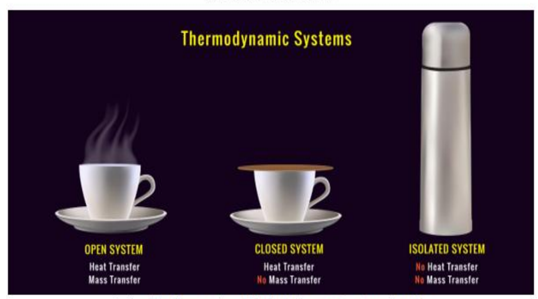


Figure 7 Thermos design automatic 24TR

Figure 8 Students observe the phenomenon

Scientific phenomenon



Sumber: https://www.zenius.net/blog/materi-konsep-dasar-termodinamika

Look at picture 2 carefully. The first picture is hot water placed in a cup and left open, the second picture is hot water placed in a cup then the cup is tightly closed, while the third picture is hot water placed in a thermos then tightly closed. From these three phenomena, please answer the questions below properly and correctly, Write down as many differences as possible between the three images above, then give reasons for your answer!

Figure 9 Observed phenomena

creativity and utilized creative thinking techniques. The results of the products designed by students before and after optimizing their creative thinking skills, as shown in Figure 6 and 7.

The Thermos design, as shown in Figure 8, remains conventional, allowing it to hold the temperature of the liquid inside for an average of 6-12 hours. As shown in Figure 9, the thermos is already able to maintain a temperature for up to 24 hours. This is due to the addition of a layer of insulation on the bottle, which acts as an insulator. Additionally, the thermos is designed to detect

Figure 10 The lecturer monitors learning activities

Figure 11 Simple thermos product 24 TR

changes in the temperature of the liquid inside automatically. This thermos is equipped with a cylindrical hose that is connected to the detector on the lid. These two components are new in Thermos design, an application of physics knowledge about thermodynamics. Based on the results of the thermos design by the students, it means that they have been able to optimize their thinking skills, as indicated by the existence of original designs. Students who are trained to apply knowledge in solving problems creatively have a meaningful impact on learning (Moreno, 2010). A person's creative ideas can be stimulated by assisting gradually to encourage their creative thinking (Al-Kamzari & Alias, 2025).

The fifth phase involves monitoring the completion of project tasks. This step is carried out in two research trials: limited trials and extensive trials. Visualization of monitoring activities is shown in Figure 10.

Lecturers conduct monitoring activities to ensure that students complete their project assignments correctly, according to the previously designed plan. This is based on Ausubel's learning theory, which posits that the formation of behavior from visible learning outcomes is achieved under specific conditions (Moreno, 2010). The results of other studies indicate that providing direction in scientific investigations is a crucial step in achieving learning goals (Clark et al., 2023; Ong et al., 2021). Reminding the target to be achieved is an efficient step in solving problems (Rusmini et al., 2021).

In phases 6 and 7, an assessment of learning outcomes and project assignment results is conducted. The assessment here emphasizes the achievement of scientific creativity indicators, especially in the field of creative individuals, which are characterized by aspects of fluency, flexibility, and originality. The products made contain novelty and have broader benefits; the visualization of products made by students and their novelty is shown in Figure 11.

The thermos in Figure 11 is designed in such a way as to overcome the problem of liquids whose temperature changes quickly due to exchange with the environment; in the thermos, there is a novelty located in the food-grade stainless steel layer; in this section, it has an originality value, namely this layer can maintain the minimum temperature for a long time. The originality value in another section is the Outer casing. This section serves to maintain the temperature in the thermos, protect it from scratches, and maximize its usability.

Based on the description above, students have been able to increase their scientific creativity with the novelty of a product they make. This aligns with Piaget's cognitive learning theory, which posits that students' cognitive development can be observed through the results of their work (Moreno, 2010). Constructivist learning theory states that the form of implementation of previously learned knowledge can be observed in the products they create. One form of student understanding of a material can be applied to everyday life problems (Santrock, 2015). Interesting ideas from students can be seen in their work (Sukamto, 2022). The social system and reaction principles built at this stage are interactions in the form of input or questions and answers between students and lecturers. This is done to improve or provide input on the results of implementing knowledge and reconstructing creative ideas through discussions and presentations.

Additionally, providing feedback on the learning process, including project assignment results and other performance outcomes, is also conducted. Furthermore, an evaluation test is conducted to measure students' scientific creativity, following good interaction and collaboration among students, between students and their lecturers, and among students themselves. One of the meaningful learning is learning from assessment results (Arends, 2008). Evaluating learning outcomes is a positive step and has a positive impact on the following learning process (Özreçberoğlu & Çağanağa, 2018; Pariona & López, 2023).

3.3 Effectiveness of the SCPjBL Model

N-gain Calculation Result

Data on scientific creativity were collected using pre-tests and post-tests following the learning process with the SCPjBL model. The findings of the N-gain calculations for every student are summarized in Figure 12.

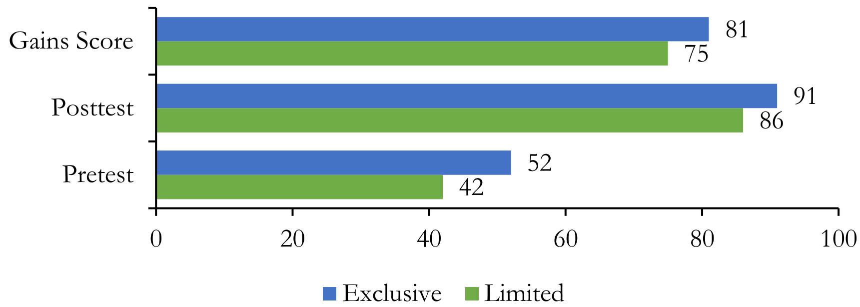


Figure 12 N-gain calculation results

With the N-gain value in the high category for two trials. While the pre-test value in both the limited trial and the extensive trial did not reach the minimum value limit determined by the study program, after implementing the SCPjBL learning model, there was a significant increase, as evident from the results of the post-test, which showed a difference of approximately 50%. The data resulted in the N-gain being categorized as high in both trials. The results of this study indicate that the application of the SCPjBL model has been proven to increase students' scientific creativity in both limited and extensive trials across two study programs at different universities. This success cannot be separated from the role of lecturers who consistently provide direction to continue spurring student creativity. According to cognitive learning theory initiated by Piaget (Slavin, 2016), emphasizing the importance of creative thinking in problem-solving is a good step in building creativity. These results are also reinforced by research conducted by Koç & Büyük (2021), which suggests that creativity in science learning, namely scientific creativity, can be facilitated by one of them to achieve their scientific creativity.

Statistical Test Results

After the N-gain calculation is carried out, the next step is to conduct a parametric statistical test; however, a normality and homogeneity test must be performed first. For more details on the results of the normality and homogeneity tests they are shown in Tables 12 and 13.

Based on Table 12, it is known that the Sig value > α = 0.05 is 0.086 for the physics study program class and 0.187 for the natural sciences study program class. According to the results of the Normality Test, the test data are normally distributed. Furthermore, a Homogeneity test is carried out to determine whether the data is homogeneous or not in both classes.

Table 12 Normality test results

	Shapiro-Wilk			
	Study program	Statistic	df	Sig.
N-gain	Physics	.939	30	.086
	Science Education	.952	30	.187

Based on Table 13, the output of the SPSS sig. N-gain of the physics study program and the science study program class is 0.960; this is greater than 0.05, so the data is categorized as homogeneous. The average results of the N-gain in students' scientific creativity for both classes are Normal and homogeneous, which can be continued to the next stage, namely the paired t-test, as shown in Table 14.

According to the paired t-test findings in Table 14, these data suggest an improvement in scientific creativity ratings following the learning process using the SCPjBL model: The t-value is negative, indicating that the post-test score is higher than the pre-test score, and the Sig-2 tailed value is < 0.05. The SCPjBL learning model achieves both expected and actual effectiveness in enhancing students' scientific creativity. Increasing students' scientific creativity cannot be separated from the quality of learning provided to students. The quality of learning is determined by many factors, including the learning process, which contains steps that encourage students to be active and creative in producing innovations (Arends, 2008; Moreno, 2010). According to research conducted by Arzak and Prahani (2023), one learning process that stimulates students' cognitive development incorporates activities that trigger the formation of a creative mentality in them. Other studies also suggest that the success of the learning process is influenced by motivational factors, particularly when learning changes extrinsic motivation into intrinsic motivation (Al-Kamzari & Alias, 2025; Blackmore et al., 2021).

Table 13 Homogeneity test results

		Levene Statistic	df1	df2	Sig.
N-gain	Based on Mean	.003	1	58	.960
	Based on Median	.016	1	58	.899
	Based on Median	.016	1	57.729	.899
	Based on trimmed mean	.004	1	58	.948

Table 14 Paired t-test results

Study program	95% Confidence Interval of the Difference				
	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Physics and Natural Science	-1.7930	.43041	-32.268	174	.000

Table 15 Results of the student response questionnaire regarding learning with the SCPjBL model

Student response components	Trials					
	Limited			Extensive		
	% Ya	Category	r	% Ya	Category	r
How lecturers teach	89%	Very Positive	R	94 %	Very Positive	R
Clarity of the phases of the SCPjBL model in the learning process.	97%	Very Positive	R	98%	Very Positive	R
Clarity of presentation of scientific creativity in the creative process	95%	Very Positive	R	98%	Very Positive	R
Ease of applying scientific creativity in making products.	95%	Very Positive	R	97%	Very Positive	R
Ease of scientific creativity testing.	100%	Very Positive	R	95%	Very Positive	R
Average	95.2 %	Very Positive	R	96.5%	Very Positive	R

Questionnaire response results

The findings of the student response questionnaire regarding the learning process with the SCPjBL model further substantiate the N-gain and paired t-test results presented in Tables 13 and 14. In detail, the results of the student response questionnaire are shown in Table 15.

Overall, 95% of students had a favorable reaction to the learning experience utilizing the SCPjBL model, as indicated in Table 15. This improved students' scientific creativity in introductory Physics 1 courses. The positive response cannot be divorced from the lecturers' effective mentoring, motivating, and facilitating during the SCPjBL model learning process. The results of student responses to the learning process using the SCPjBL model are positive. Based on these findings, The teacher's instruction is straightforward for learners to grasp, in line with the concepts proposed by Vygotsky's social theory (Arends, 2008; Moreno, 2010). According to the findings from the response survey, students believed that their creativity in science had grown. This demonstrates that using the SCPjBL model can be both practical and successful in enhancing students' scientific creativity in college-level introductory physics courses.

The completeness of all indicators of scientific creativity, both in limited trials and extensive trials, which are reviewed from the three main dimensions of creative thinking, namely the fluency dimension, the flexibility dimension, and the originality dimension, are shown in Figure 13.

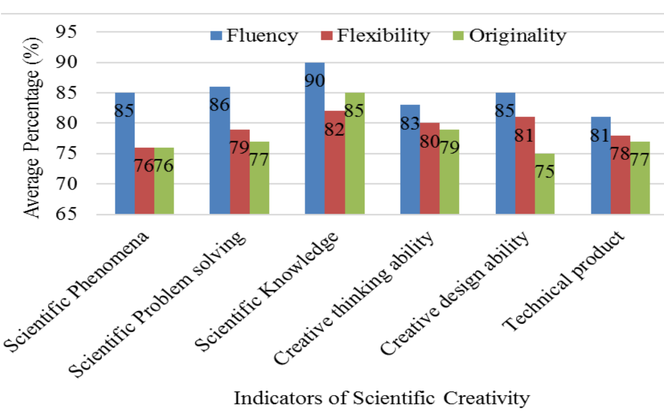


Figure 13 Percentage of completion of students' scientific creativity indicators

Based on Figure 13, the average percentage of completion of the scientific creativity indicator has generally reached the minimum completion percentage criterion of 75%. There is a creative design ability indicator that gets a score of 75; this score is lower than the other scores. This low score is caused by several factors, including students who were previously less familiar with the originality design aspect, so many students still feel new to this instruction. The score of scientific creativity indicator of knowledge exploration receives the highest score because students have previously been trained to deepen their scientific knowledge. Meaningful learning will be easier for students who have had previous positive experiences (Arends, 2008). This result aligns with the findings of previous studies, which suggest that scientific creativity in some students requires intensive training (Al-Kamzari & Alias, 2025; Nur et al., 2018). This aligns with the theory of meaningful learning, which posits that an active learning atmosphere can shift students' learning motivation from extrinsic to intrinsic motivation (Slavin, 2016). Previous studies support the findings of this study, particularly that problem-oriented learning activities enhance students' scientific creativity (Sidek et al., 2020; Suyidno et al., 2020).

4. CONCLUSION

The development of the scientific creativity project-based learning model in physics education is carried out in four stages, namely the preliminary study stage, the development stage, the validation stage, and the implementation stage. The development of this learning model has achieved feasibility as a learning model, specifically in terms of validity. The validity score reaches 3.9, indicating a very valid category. Practically, the learning model that has been developed and tested on students yields practical results, with the level of implementation of each phase reaching an average score above 2.5, categorized as very good. While the third model's feasibility indicator is effective, in this SCPjBL model, the score obtained based on the N-gain calculation achieved an excellent increase, with an N-gain score of 0.75, placing it in the high category. In the extensive trial, it achieved a score of 0.81, also falling within the high category. To ensure that the results of developing this SCPjBL model meet the feasibility criteria as a physics learning model. Recommendations for further research suggest that this learning model needs to be expanded in terms of its feasibility test to include several universities beyond the physics education study program. The advantage of using this model is that students are not only how to produce a product. However, students need to emphasize scientific reasons with science exploration as the main milestone. Suggestions for further researchers that this learning model needs to be further developed with an AI technology-based approach. This aligns with current knowledge trends.

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