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The Effect of Guided Discovery Learning and Scientific Literacy on Senior High School Students Science Process Skills in Newton's Laws

Debby Aslamia*, I Made Astra, and Firmanul Catur Wibowo
Physics Education, Jakarta State University, Jakarta, Indonesia
*aslamia.debby@gmail.com

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Abstract

The goals of this research are to (1) compare the scientific process abilities of students with high and low science literacy levels in the guided discovery learning group to those of students in the expository group and (2) determine how learning models interact with science literacy to impact science process capabilities. The study used a 2x2 factorial design and was quantitative, using a quasi-experimental methodology. All eleventh graders at IPA MAN 11 in Jakarta were eligible to participate in this research. Utilizing a purposive sampling technique, the sample was derived from two classes: one that was taught using the guided discovery learning model and another that was taught using the expository model. Within each class, there were two subgroups: those with high science literacy and those with low science literacy. Data is gathered using a pre-and post-test approach using instruments such as a science literacy questionnaire and a test of scientific process abilities. According to the study's findings, students in the guided discovery learning group exhibited significantly better science process skills than those in the expository group, regardless of whether their science literacy level was high or low. Scientific process abilities are unaffected by the learning model's connection with scientific literacy. On the other hand, competency in the scientific method is another area in which science literacy helps. The interplay between good scientific literacy and the guided discovery learning paradigm affects students' abilities to carry out the scientific method. When paired with strong scientific literacy, the guided discovery learning methodology may help students become more proficient in the scientific process. This finding indicates that combining discovery-based learning and technology can be an innovative alternative to science learning.

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INTRODUCTION

The scientific approach to learning physics can be applied through science process skills. It is an important indicator in transferring the knowledge needed to solve problems and gain experiment experience. It serves as a fundamental foundation for developing students' systematic, critical, and analytical thinking skills through a series of structured experimental activities. Through science process skills, students not only gain conceptual understanding but also develop practical skills in conducting scientific investigations, analyzing data, and constructing conclusions based on empirical evidence (Boyssorongan et al., 2024; Nurhuwaida et al., 2022; Nuzulia & Nurmaliah, 2017; Virginia et al., 2018). Science process skills are the basis of problem-solving in science and the scientific method, so it is very important to study (Hajian et al., 2011; Kumala & Sudibyo, 2020; Nadia et al., 2021; Risda et al., 2023; Zainuddin et al., 2020). It includes a set of fundamental skills in scientific methodology that include the ability to formulate hypotheses, make data-driven predictions, identify and analyze patterns, and understand the relationships between variables in an experimental context (Sani & Anggraini, 2015; Utami et al., 2022).

Based on several studies, it was found that students' science process skills are still very lacking. The problem that occurs, in general, is the lack of science process skills of junior high and high school students, due to the learning approach factors used, namely the learning model and the condition of students, science literacy. In the learning process, teachers usually use the expository method, which is the method of verbal delivery of material, so this method causes passive student responses and a lack of interaction in thinking activities. In addition, students' low science process skills were also identified as a consequence of the lack of practical experience in physics experimental activities. This problem arises as an implication of various factors, including limited laboratory infrastructure, such as the lack of availability of adequate practicum tools and materials (Adawiyah et al., 2022; Carin, 1993; Karimah et al., 2023).

Several solutions can be done to overcome these problems, namely by using scientific approaches and media in the teaching and learning process. One approach that is considered suitable is the Guided Discovery Learning Model (GDL). GDL is a learning model that combines learning methods centered on teachers and students. GDL, also known as the guided discovery model, is a constructivist pedagogical approach that integrates the systematic mentoring process with learners' independent exploration. This learning model facilitates learners in constructing their own knowledge through a series of structured discovery activities in which the educator acts as a facilitator who guides the learning process (Carin, 1993; Danianty, 2022).

Various empirical studies have proven the effectiveness of the GDL learning model in improving students' science process skills. Comparative studies show that GDL provides more optimal results than other conventional learning models (Adawiyah et al., 2022; Ahmad et al., 2021; Boyssorongan et al., 2024; Handayani et al., 2017; Virginia et al., 2018). In line with that, the results of the study (Fitri et al., 2022; Hidah, 2022) revealed that GDL is very effectively used to improve science process skills and student learning outcomes.

The problem of science literacy skills is also a factor causing students' weak science process skills. Science literacy is a multidimensional concept that includes a comprehensive understanding of science and its practical applications in daily life. This includes the ability to integrate scientific knowledge in problem-solving, the development of science-based critical thinking skills, and the cultivation of interest and curiosity towards scientific phenomena (Danianty, 2022; Gultom & Alwi, 2024; Utami et al., 2022).

Indonesia's science literacy skills are still low. According to the 2022 PISA (Programme for International Student Assessment) results, Indonesia's score dropped to 383, and its ranking rose slightly to 66 out of 80 countries. The low level of science literacy is also caused by poor reading habits among students, who often do not want to take the time to read.

Research Danianty (2022), Ridlo (2019), and Utami et al. (2022) showing that students' science literacy skills have a significant influence on students' science process skills. Based on the results of several previous studies, it can be concluded that the GDL model is very suitable for use to improve students' science process skills, but some of these studies still have shortcomings. Namely, these studies do not add learning media that can support the model, so that the problems of experimental activities such as the time required for a long time and the lack of laboratory tools and materials have not been overcome.

To overcome these shortcomings, researchers added media that supports the learning process, namely the PhET virtual laboratory. The PhET virtual laboratory is one of the alternative models for overcoming the problems of practicum implementation (Abdjul et al., 2019; Gunawan et al., 2019). It is an ICT-based learning process that can be used as an alternative learning solution to the practicum method (Idrus et al., 2021; Manikowati et al., 2018).

This study will analyze the effect of guided discovery learning and scientific literacy on senior high school students' science process skills in Newton's laws. The novelty of this study is the addition of learning media in the form of PhET simulations. In addition, the test instruments used are the latest and valid scientific literacy and science process skills test instruments.

METHODS

This research made use of a quantitative approach based on a quasi-experiment design. This research uses a 2 x 2 factorial design, which is typical of quasi-experimental methods. In this study, the independent variable is scientific literacy, which includes indicators of scientific knowledge, an investigation of the nature of science, science as a way of thinking, and the interaction between science, environment, technology, and society. The dependent variable is science process skills with indicators such as observation, use of numbers, classification, measurement, communication, prediction, inferential, identification and control of variables, data interpretation, hypothesis formulation, operational definition of variables, and experiments. The treatment variables are divided into guided discovery learning and expository learning. The moderator variables are high scientific literacy and low scientific literacy.

The accessible population in this study was all students of class XI IPA MA Negeri 11 in Jakarta in the 2024/2025 academic year. The sample in this study was selected using a purposive sampling technique, namely 66 students divided into two classes: the experimental class given guided discovery learning treatment and the control class given expository learning treatment. The experimental class and the control class each consisted of 33 students. After selecting samples from each class (experimental and control groups), both took a science literacy test. The test results were then sorted from the highest to the lowest and ranked. Using the results of this ranking, the 27% highest scores were considered the upper group, representing students with a high level of science literacy, while the 27% lowest scores were considered the lower group, representing students with a low level of science literacy (Alanazi, 2024; Arikunto, 1999).

To get this information, a test question instrument was used. Using markers of scientific process abilities and science literacy, the exam questions were crafted from content related to Newton's laws. The scientific literacy exam consisted of multiple-choice questions, whereas the science process skills test included descriptive questions. Before its implementation, the assessment tool was pilot-tested with 45 students who were not part of the study population. Following administration, the instruments undergo examination for validity, reliability, difficulty level, and discriminating power. Based on the data processing findings, the scientific process skills test instrument had 12 valid and appropriate questions out of 15, and the science literacy test instrument had 30 valid and acceptable questions out of 35. First, we checked for normality and homogeneity in the data analysis process. The results of the normality test produced a sig. value of 0.172, indicating that the data was normally distributed for each group. The results of the homogeneity test produced a sig. value of 0.562, indicating that the data had homogeneous variance. Then, we use two-way ANOVA and the T-test to assess our hypotheses. The research hypothesis of this study is; that there is a difference in students' science process skills between the group given the guided discovery learning model and the group given the expository learning model; there is an interaction effect between the learning model and science literacy on students' science process skills; there is a difference in students' science process skills between the group given the guided discovery learning model and the expository learning model in the group of students with high science literacy; there is a difference in students' science process skills between the group given the guided discovery learning model and the expository learning model in the group of students with low science literacy. Figure 1 is a visual representation of the research process.

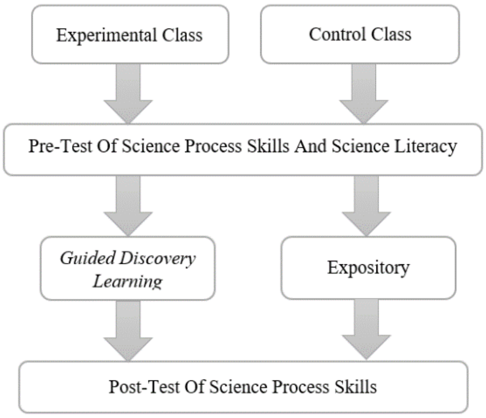

Figure 1 Research procedure

This study consisted of two classes: a class with the GDL model as an experimental class and an expository learning model as a control class. Each class was given a pre-test of science process skills and a pre-test of science literacy. After that, learning activities were carried out in each class according to the treatment plan. the material presented was Newton's Law. At the end of the meeting, each class was given a post-test on science process skills. The treatment design that will be carried out in this study is as follows.

Table 1 Class Treatment Design

	Eksperimental Class (GDL)	**Control Class (Expository)**
Number of Meetings	5	5
Execution Time	November 2024	November 2024
Pre-Test	Provision of scientific literacy test instruments and pre-test instruments for scientific process skills on Newton's Law material.	Provision of scientific literacy test instruments and pre-test instruments for scientific process skills on Newton's Law material.
Implementation of Learning	**Phase 1: Establishing Learning Objectives** • Students can understand and explain Newton's three laws and can apply the concepts in real situations. **Phase 2: Increasing Interest and Motivation** • The teacher asks students, "What happens to an object when we push or pull it?"	**Phase 1: Introduction** • The teacher explains the learning objectives, namely that students will understand Newton's three laws of motion and their applications in everyday life. • The teacher and students discuss simple examples in everyday life, such as driving a car or playing ball.

	• Students discuss several real-world examples such as riding a bike, playing ball, or using a toy car.
	Phase 3: Providing Problems or Guiding Questions
	• The teacher invites students to think, "How do we determine if the force applied to an object is enough to move it?"
	• The teacher provides guiding questions for students to dig deeper (short demonstrations if necessary).
	Phase 4: Exploration and Investigation
	• The teacher invites students to use the PhET simulation titled "Forces and Motion".
	• In this simulation, students can:
	1. Arrange Objects: The teacher asks students to select objects with different masses and change the forces applied to them.
	2. Newton's First Law Experiment: The teacher invites students to observe how an object that is not given a force will remain still, and how an object that is given a force will move. Ask them to record the results of their observations.
	3. Newton's Second Law Experiment: Students can change mass and force to see how they affect acceleration. Ask students to calculate acceleration based on the force and mass used.
	4. Newton's Third Law Experiment: The teacher invites students to use two different objects and observe the reactions that occur when they collide with each other.
	Phase 5: Discussion and Reflection
	• After the experiment, the teacher invites students to discuss in small groups about the results they get.
	• The teacher gives guiding questions, for example:
	  ○ "What happens to the object when the force is applied?"
	  ○ "How does mass affect acceleration?"
	  ○ "What are other examples in everyday life that illustrate Newton's third law?"
	Phase 6: Summarizing Findings
		Phase 2: Presentation of Material
		• The teacher explains Newton's First Law
		○ Definition: Objects tend to remain at rest or move in a straight line at a constant speed, unless there is a force that changes the state.
		○ PHET Simulation: Use the "Forces and Motion" simulation to show an object that remains at rest and is then subjected to a force.
		• The teacher explains Newton's Second Law
		○ Definition: The acceleration of an object is proportional to the total force acting on it and inversely proportional to its mass (F = m*a).
		○ PHET Simulation: Show how changing the force and mass affects acceleration in the simulation.
		• The teacher explains Newton's Third Law
		○ Definition: For every action, there is an equal and opposite reaction.
		○ PHET Simulation: Demonstrate by applying force to an object and showing the reaction of another object.
		Phase 3: Explanation
		• Students provide in-depth explanations of each law with real-life examples.
		• The teacher invites students to share their experiences relevant to the laws.
		Phase 4: Discussion and Q&A
		• The teacher asks students to ask questions about aspects that are unclear.
		• Students discuss how these laws are applied in real-life situations.
		Phase 5: Practice and Application

	• The teacher asks students to summarize each of Newton's laws based on the experiments they have conducted. • Students present their findings, and the teacher helps summarize and emphasize the main concepts of Newton's three laws. **Phase 7: Application of Concepts** • The teacher provides a case study: The teacher gives students an everyday situation, such as describing how Newton's laws are applied in sports (e.g., when jumping, kicking a ball, or playing basketball) and asks them to explain the relevant law. • The teacher provides independent work asking students to find real-life examples at home or around them that show the application of Newton's laws and write a short report. **Phase 8: Assessment and Feedback** • The teacher gives students a short quiz about Newton's laws and their applications. • Students can also create a poster that summarizes Newton's laws and examples. **Phase 9: Final Reflection** • The teacher asks students to write down one new thing they learned and one question they still have about Newton's laws. Discuss the questions as a class to deepen understanding.	• The teacher invites students to pair up and use the pHET simulation to solve several challenges: ○ Calculating the force required to move a certain object. ○ Applying the third law to understand the interaction between two objects. • Students write a short report on the experiment they conducted with the simulation. **Phase 6: Closing** • The teacher summarizes Newton's three laws and their applications • Students write down one new thing they learned and one question they still have. **Phase 7: Evaluation** • The teacher gives a quiz with several multiple-choice questions and an essay on Newton's laws. • The teacher gives students the task of finding additional examples of Newton's laws in everyday life and writing them down.
Post-test	Providing science process skills test instruments for Newton's laws.	Providing science process skills test instruments for Newton's laws.

RESULTS AND DISCUSSION

We will discuss the research data about high school students' science process skills. The data were obtained after working on tests in Newton's law of motion learning activities with guided discovery learning and expository models. Students in each class are divided into two groups according to their scientific literacy levels; these groups are determined by the results of the students' science literacy assessments. The division into two groups aims to see the differences between the low science literacy group and the high science literacy group in each class, which is in accordance with the objectives and hypotheses of the research.

Table 2 Descriptive statistics

Science Literacy (B)	Learning model (A)			
	Guided Discovery Learning (A1)		Expository (A2)	
High Science Literacy (B1)	N	9	N	9
	Mean	95.56	Mean	89.56
	Median	97.00	Median	90.00
	Std.Deviation	3,468	Std.Deviation	4.64
Low Science Literacy (B2)	N	9	N	9
	Mean	67.00	Mean	64.11
	Median	67.00	Median	63.00
	Std.Deviation	4.5	Std.Deviation	3.76
Total	N	18	N	18
	Mean	81.33	Mean	74.06
	Median	83.00	Median	75.00
	Std.Deviation	7.276	Std.Deviation	8.861

According to the descriptive statistical test results shown in the table above, students in the low and high science literacy groups had different average values for science process skills when taught using the expository model compared to guided discovery learning. Similarly, when looking at the overall findings, it is clear that the students in the guided exploration group had higher average values for scientific process abilities than those in the expository model.

Using the findings from the test of between-subjects effects, we ran a two-way ANOVA on the data to see if hypotheses 1 and 2 were supported. Hypothesis 1 is a difference in students' science process skills between the group given the guided discovery learning model and the group given the expository learning model, and hypothesis 2 is that there is an interaction effect between the learning model and science literacy on students' science process skills. The table below displays the outcomes. The purpose of the first hypothesis test using this primary impact is to compare the scientific process abilities of students taught using the expository and guided discovery learning models. Suppose we want to know whether the learning models and science literacy interact to affect the ability to carry out the scientific method. In that case, we may run hypothesis 2 with this interaction effect. Here, we're talking about two types of learning models: guided discovery learning and expository.

Table 3 Tests of between-subjects effects

Dependent Variable: science process skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2193.139[a]	17	129.008	4.479	.001
Intercept	169430.726	1	169430.726	5881.877	.000
Model	247.141	1	247.141	8.580	.009
Science literacy	1055.644	10	105.564	3.665	.008
Model * Science literacy	293.678	6	48.946	1.699	.179
Error	518.500	18	28.806		
Total	220023.000	36			
Corrected Total	2711.639	35			

a. R Squared = 0.809 (Adjusted R Squared = 0.628)

Table 3 shows the results of the Two-Way ANOVA test. For hypothesis 1, it was found that the learning model had a significance value of 0.009 < 0.05 for science process skills. Therefore, it can be concluded that science students' process skills differ significantly between the guided discovery learning model and the expository model. A significant value of 0.179 > 0.05 is shown for hypothesis 2, which examines the impact of the learning model and science literacy on students' science process skills. Therefore, it can be concluded that this interaction has no effect.

In addition, a table containing the outcomes of the t-test data processing was created for testing hypotheses 3 and 4 using the independent sample t-test. To determine whether students in the high science literacy category who were taught using the guided discovery learning model or the expository approach exhibited different proficiency levels in the scientific process, we conducted a simple impact test of hypothesis 3. Hypothesis 3 is a difference in students' science process skills between the group given the guided discovery learning model and the expository learning model in the group of students with high science literacy.

Table 4 Independent sample t-test hypothesis 3

	t	**df**	**Sig (2-tailed)**	**Mean Difference**	**Std. Error Difference**
Equal Variance Asummed	3.107	16	0.007	6.00000	1.930
Equal not Variance Asummed	3.107	14.813	0.007	6.00000	1.930

According to the independent Sample T-test results shown in the table above, a significant difference ($p = 0.007$) was discovered in the value of the science process skills of high science literacy students when they were taught using either the guided discovery learning model or the expository model.

In addition, we used the hypothesis 4 test with a simple effect to compare the scientific process abilities of students in the poor science literacy group who were taught using the expository model to those who were taught using the guided exploration model. Hypothesis 4 states that there is a difference in students' science process skills between the group given the guided discovery learning model and the expository learning model in the group of students with low science literacy.

Table 5 Independent sample t-test hypotheses 4

	t	**df**	**Sig (2-tailed)**	**Mean Difference**	**Std. Error Difference**
Equal Variance Asummed	3.107	16	0.007	6.00000	1.930
Equal not Variance Asummed	3.107	14.813	0.007	6.00000	1.930

According to the results of the independent sample t-test in the table above ($p = 0.159$), a significant difference in the science process skills value was not observed between the low science literacy students in the group taught using the guided discovery learning model and the low science literacy students taught using the expository model.

Hypotheses 2 and 4 are rejected based on the findings of the tests mentioned above. However, hypotheses 1 and 3 are supported. Based on the average values, we can observe that the guided discovery learning group has better scientific process abilities (81.3 vs. 74.0), supporting the first hypothesis that this learning style is superior to the expository one.

In the guided discovery learning model, the instructor takes on the role of a guide rather than a teacher; as a result, students in this model are expected to demonstrate traits like independence, bravery, and confidence. The teacher's role is to help students develop these traits while also boosting their motivation to learn and self-confidence. To help their pupils develop better cognitive capacities, teachers should model critical, creative, and inventive thinking for them.

Consistent with what is indicated, guided discovery learning is an action in the learning process where students engage in the conceptual construction of their knowledge. An important part of guided discovery learning is the motivating component. Guided discovery learning is superior to cognitive content learning because it focuses on the social, emotional, and cognitive domains of learning rather than just the cognitive one. For students' spirituality, personality, and intelligence to be valuable in their lives now and in the future, they must develop their cognitive, emotional, and social qualities.

The second hypothesis states that the interplay between scientific literacy and learning models significantly impacts the abilities of the science process. This is not acceptable since, in most cases, pupils' reading levels differ, necessitating a tailored approach to instruction. In contrast to the expository model, which emphasizes the teacher, the guided discovery learning approach places the students at the center of the learning process. As a result, students with these personality traits will find that they get bored quickly using this model.

The findings are consistent with those of (Lathifah et al., 2025; Karimah et al., 2023; Utami, 2022), who said that GDL emphasizes students' ability to understand concepts and find solutions to problems. Teachers are not the primary source of learning; they only guide and provide the facilities students need. Likewise, in line with the opinion of (Utami et al., 2022; Purwandari et al., 2024) this type of expository learning is often used to convey new concepts that require deep and detailed understanding. In its implementation, expository learning involves presenting information, explaining concepts, conducting directed exercises, and providing feedback to deepen students' understanding.

The third hypothesis is that the guided exploration learning mode enhances the value of scientific process skills in the high science literacy group compared to the expository model. This is evident from the mean value in Table 1, which shows that the expository model has an average of 89.56, and the GDL model has an average of 95.56. Students with strong scientific literacy levels might benefit even more from a guided discovery learning paradigm, as it encourages them to think critically, creatively, and collaboratively to solve each learning challenge. On the other hand, students with strong scientific literacy skills will not be able to thrive in an expository model classroom because their attention will remain fixed on the teacher's presentation of the material rather than on how to apply what they've learned.

The fourth hypothesis is that compared to the expository model, the guided discovery learning model enhances the scientific process abilities of poor science literacy students more than the expository model. The difference between the guided discovery learning model's average value of 67 and the expository model's average value of 64.11 for scientific process skills is not statistically significant, as shown in Table 1 above. This outcome is a direct consequence of pupils' very poor levels of scientific literacy, which prevents the learning model from having the desired effect on them. Improving the quality of instruction and, by extension, the student's personal development, depending on their level of scientific literacy. Students with low science literacy are not very enthusiastic about following it. When faced with a problem, they sometimes communicate with friends to find a solution and sometimes ignore it; especially if the problem is difficult, they will give up more easily (Danianty, 2022; Mayasari et al., 2022).

Overarchingly, this study's outcomes consistent with previous research (Adawiyah et al., 2018), this study found that guided discovery learning outperformed investigative learning in enhancing students' abilities to perform the scientific method. Consistent with this, studies have shown that guided discovery learning significantly improves students' skills and learning outcomes in the scientific process. The guided discovery learning paradigm significantly impacts students' scientific process abilities, according to research (Boyssorongan et al., 2024; Fitri et al., 2022; Kumala & Sudibyo, 2020; Virginia et al., 2018).

CONCLUSION

The study's findings are as follows: 1) students' science process skills were significantly higher in the guided discovery learning group compared to the expository group; 2) there is no significant effect of learning models on science process skills when interacting with science literacy; 3) in the high science literacy group, the guided discovery group outperforms the expository group when it comes to science process skills; and 4) in the low science literacy group, the guided discovery group outperforms the expository group when it comes to science process skills, but the differences are not statistically significant. When paired with strong scientific literacy, the guided discovery learning methodology may help students develop stronger abilities in the scientific method. These findings indicate that combining discovery-based learning and technology can be an innovative alternative to science learning.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, IMA & FCW; methodology, IMA, FCW, & DA; formal analysis, IMA & FCW; writing-preparation of the original draft, DA.

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AUTHOR PROFILES

Name: Debby Aslamia
Email: Aslamia.Debby@Gmail.Com
Affiliation: Universitas Negeri Jakarta

Name: Prof. Dr. I Made Astra, M.Si
Email: Imadeastra@Gmail.Com
Profession: Lecturer
Affiliation: Universitas Negeri
Google Scholar: I Made Astra

Name: Dr. Firmanul Catur Wibowo, M.Pd
Email: Fcwibowo@Unj.Ac.Id
Profession: Lecturer
Affiliation: Universitas Negeri
Google Scholar: Firmanul Catur Wibowo