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APPLICATION OF THE GENERATIVE LEARNING MODEL ASSISTED BY E-MODULES AND PHET SIMULATIONS TO IMPROVE STUDENTS' PROBLEM-SOLVING SKILLS ON STRAIGHT-LINE MOTION MATERIAL FOR GRADE XI AT SMA YPK

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Abstract

This study aims to determine the effectiveness of implementing a generative learning model assisted by e-modules with PhET simulation in improving students' problem-solving skills on the topic of straight-line motion in Grade XI of SMA YPK. The researcher employed a quantitative approach with a pre-experimental research design, specifically the one-group pretest-posttest design. The sample in this study consisted of all 12 Grade XI students from SMA YPK Pontianak. Data collection techniques included tests and observations. The tests administered were a pre-test and a post-test. The instruments used in this study were the test instruments and a teaching module containing Student Worksheets (*Lembar Kerja Peserta Didik*) and a Lesson Plan (*Rencana Pelaksanaan Pembelajaran*). Data analysis in this study utilized the Wilcoxon Signed Rank Test to determine the mean difference between the pretest and posttest scores, and the N-Gain test was used to determine the magnitude of the learning model's effectiveness. The results of the Wilcoxon Signed Rank Test showed an Asymp. Sig. (2-tailed) value of 0.002 (< 0.05), indicating that there is a significant difference between the pretest and posttest scores. This means that the treatment given had a significant effect on improving students' problem-solving skills. This finding is supported by the N-Gain calculation, which produced an average N-Gain value of 0.73, indicating that the effectiveness falls into the high category.

Keywords: Generative Learning Model, E-Module, PhET Simulation, Problem-Solving Skills, Linear Motion

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INTRODUCTION

In physics instruction, students are guided to formulate concepts based on phenomena observed in their immediate environment. However, many students perceive physics as a difficult and intimidating subject. This perception is generally attributed to the assumption that physics necessitates the memorization of numerous formulas, relies heavily on calculations to solve problems, and is delivered in a monotonous learning atmosphere factors that collectively contribute to student disengagement and a lack of conceptual comprehension (Charli, 2018; Ekawati, 2018; Sjahrir &

Jatmiko, 2015). One of the fundamental topics that serves as a foundation for understanding more advanced physical concepts is straight-line motion. Nevertheless, studies have shown that students' problem-solving abilities in this specific topic remain relatively low (Mustofa & Rusdiana, 2016; Pratiwi & Alyani, 2022). In the context of physics, problem-solving is closely correlated with the understanding of physical concepts. The factors influencing this cognitive process include the structure of students' existing knowledge as well as the characteristics of the problems being addressed (Sujarwanto, 2014). The problem-solving framework proposed by Heller (1992) comprises five distinct stages: visualizing the problem, constructing a physics description, planning a solution, executing the plan, and checking and evaluating the outcome.

The factors influencing students' problem-solving abilities can be categorized into external and internal factors. According to Hasmira (2023), internal factors include students' interest and cognitive abilities, whereas external factors encompass the learning models and methods implemented by the teacher. Consequently, enhancing students' problem-solving skills necessitates the application of varied instructional models. To address this need, the present study employs a generative learning model assisted by an e-module and complemented with PhET simulations to improve students' problem-solving abilities..

The selection of SMA YPK as the research site was based on preliminary observations and interviews with physics teachers, which revealed that the majority of students continue to encounter difficulties in solving problem-solving-based questions. Furthermore, instruction has predominantly relied on conventional teaching models, and interactive learning media such as PhET simulations have never been employed. These conditions render SMA YPK a relevant location for implementing the generative learning model assisted by an e-module and complemented with PhET simulations, in order to investigate the extent to which this instructional approach can effectively enhance students' problem-solving abilities..

Based on the results of interviews conducted with teachers at SMA YPK, it was found that students experience difficulties in comprehending the concepts of velocity and acceleration. This issue is corroborated by the study of Wati et al. (2020), which reported that among students with a deficient understanding of acceleration and velocity concepts, 68% exhibited misconceptions, while 20% of students perceived that negative velocity does not exist, and another 20% assumed that a stationary object has no acceleration—or equivalently, possesses zero acceleration. Furthermore, the teachers also stated that students' physics examination scores remain relatively lower compared to those of other subjects. This finding is consistent with the research conducted by Azizah, Yuliati, and Latifa (2015), which revealed that 70% of high school students from three different schools obtained physics test scores below the minimum mastery criterion (KKM).

One effective instructional model to implement is the generative model. The generative learning model is a pedagogical approach grounded in constructivist theory, in which students are actively engaged in the learning process to discover and construct their own knowledge. The steps proposed by Osborne & Wittrock (1985) within this model encompass five stages: exploration, elicitation of ideas, challenge and restructuring, application, and review. In this model, considerable emphasis is placed on the active role of students, whereas the teacher functions as a facilitator and mediator who guides the learning process (Maryani, 2020). Consequently, the use of this model is expected to foster a conducive and enjoyable learning atmosphere. Furthermore, the implementation of the generative learning model will be more effective when combined with instructional media that can enhance student participation and learning activities.

One instructional medium that can be employed to address this issue is the use of teaching materials in the form of e-modules. E-modules possess the potential to enhance the appeal of the learning process, as they can present content in the form of images or videos that can be accessed and reviewed repeatedly by students (Puspitasari, 2019). Furthermore, the use of e-modules facilitates distance learning, since they can be accessed across various devices such as laptops, smartphones, computers, and others at any time and from any location. This undoubtedly contributes to increasing students' motivation to learn physics (Oktaviana & Putri, 2020). The ease of use and interactive nature of e-modules are expected to enable students to engage in self-directed learning.

According to Marpaung et al. (2021), PhET simulations constitute a website developed by the University of Colorado that provides a variety of simulations for both classroom and individual learning. The use of PhET simulations can serve as an effective solution to the existing problems. This virtual laboratory has been demonstrated to exert a positive impact on the development of students' skills, attitudes, and conceptual understanding. According to Asyana and Arini (2020), the implementation of PhET simulations in practical instruction has received highly positive responses from students. PhET simulations also play a role in assisting students to comprehend complex physics concepts, as well as enhancing their scientific process skills, scientific attitudes, and conceptual understanding more profoundly. Therefore, the use of PhET simulation-based instructional media in the form of interactive electronic modules is considered a relevant approach in contemporary physics education. Previous research has shown that the use of electronic modules supported by PhET simulations can improve students' conceptual understanding and learning interest (Meftahudin et al., 2024). Based on the aforementioned issues, a study entitled "Application of the Generative Learning Model Assisted by E-Modules and PhET Simulations to Improve Students' Problem-Solving Skills on Straight-Line Motion Material for Grade XI at SMA YPK" is crucial to be conducted.

METHOD

The researcher adopted a quantitative approach, utilizing a pre-experimental research design, specifically the one-group pretest-posttest design, in which only a single group of participants is employed (Arvianti et al., 2025). The structure of this design is presented in Table 1. The participants are administered a test prior to the intervention (pretest) and subsequently re-tested following the intervention (posttest). Subsequently, the researcher compares the pretest and posttest scores to determine the effect of implementing the generative learning model assisted by e-modules and PhET simulations on improving students' problem-solving abilities. The sample in this study comprised all 12 students enrolled in grade XI at SMA YPK Pontianak.

Table 1. One Group Pretest Posttest Design

Pretest	Intervention	Postest
Q1	X	Q2

The data collection techniques employed in this study comprised tests and direct observations. The tests were administered both prior to (pretest) and following (posttest) the instructional intervention. Direct observations were conducted to monitor student activities throughout the classroom learning process. The instruments utilized in this research consisted of the tests, accompanied by teaching modules which contained student worksheets (LKPD) and lesson plans (RPP). The test items, totaling 20 questions, were adopted from the study conducted by Silitonga et al. (2024), which had previously undergone validity and reliability testing. The data analysis technique employed in this study was the Wilcoxon Signed Rank Test, which was used to ascertain the mean difference between the pretest and posttest scores.

RESULTS AND DISCUSSION

This study was conducted to improve students' problem-solving abilities through the implementation of the generative learning model assisted by e-modules and PhET simulations in grade XI of SMP YPK. A total of 12 students participated in this research. Each student initially completed a pretest consisting of 20 multiple-choice questions, comprising five main questions and four testlets, and subsequently received instruction on straight-line motion over the course of five meetings. Following the intervention, the students completed a posttest with the same number of questions. After both the pretest and posttest were administered, an analysis of the students' problem-solving ability profiles was carried out using the problem-solving ability categorization framework (Ariani, 2017).

The first issue addressed in this study was to identify the profile of students' problem-solving abilities at SMA YPK. From the students' responses, the average percentage for each problem-solving ability component was obtained. The following presents the percentage of students' problem-solving abilities for each aspect based on Heller's stages, including: the ability to sketch the problem, describe the known and unknown variables, plan a solution, and execute the solution plan, both before and after the implementation of the generative learning model.

Table 2. Profile of Students' Problem-Solving Abilities Prior to Intervention

Stage	Total Score	%	Category
Visualize The Problem	22	36,6%	Low
Physics Description	22	36,6%	Low
Plan A Solution	19	31,67%	Low
Execute The Plan	15	25.00%	Low
Average	19.5	32.05%	Low

The profile of students' abilities prior to the implementation of the learning model is presented in Table 2. In the first Heller stage, namely the ability to sketch the problem, a percentage of 36.67% was obtained, falling into the low category. This percentage indicates that, overall, students were still unable to depict the problems presented in each question. Following the generative learning intervention, the ability to sketch the problem demonstrated an increase to 81.67%, classified as high. This improvement is attributed to the fact that students were not previously accustomed to illustrating problems when solving questions. Students were unaccustomed to solving problems using structured problem-solving procedures, as their learning experiences at school had typically involved teacher-directed instruction rather than independent problem-solving (Pratiwi, 2018). In the visualize the problem stage, students are guided to comprehend the problem situation by creating visual representations, such as diagrams or drawings, and identifying the known and unknown information. This stage aligns with the orientation and prior knowledge activation phase in the generative learning model, as students connect the given problem with their existing experiences and physics concepts, thereby forming a meaningful initial representation that serves as a foundation for problem understanding (Wittrock, 1994).

The second Heller stage, namely describing the physical situation—including known and unknown variables—yielded a percentage of 36.67%, categorized as low. This percentage indicates that students were still unable to determine the relevant physics concepts or principles applicable to the problem, which was attributed to their insufficient comprehension of the given questions. After the generative learning intervention, the ability to describe the known and unknown variables showed an increase to 81.67%, falling into the high category. Students' inadequate conceptual understanding contributed to their limited problem-solving abilities (Ayumniyya, 2021). As Khaeruddin, cited in Suardika (2013), stated that problem-solving can also be defined as an individual's capacity to discover answers based on previously acquired understanding. In the physics description stage, students are required to describe the problem conceptually by identifying the physical quantities involved, selecting relevant concepts, principles, and laws of physics, and formulating relationships among variables. This stage has a direct connection with the focus or idea elicitation phase in generative learning, wherein students actively construct conceptual understanding of the physical phenomena under investigation. This constructive process enables students to build meaning regarding the concepts employed, ensuring that problem-solving is not merely procedural but also grounded in deep conceptual understanding (Osborne & Wittrock, 1983).

The third stage, planning a solution, yielded a percentage of 31.67%, classified as low. This percentage indicates that all students were still unable to determine the appropriate solution equations for solving the problems presented. This difficulty arose because students experienced challenges in devising solution strategies to address the problems. Following the generative learning intervention, the ability to plan a solution showed an increase to 85.00%, falling into the high category. Students' ability to design solution strategies influences the accuracy of their responses in solving problems (Mustofa, 2016). Students who do not comprehend the problems presented in the questions may also experience low ability in designing solutions to resolve them. The plan a solution stage in Heller's problem-solving framework is closely related to the challenge and conceptual restructuring phase in generative learning. At this stage, students plan their solution strategies by determining the steps to be taken and selecting appropriate equations based on the physics concepts they have understood. These activities encourage students to test their initial ideas and adjust them according to the demands of the problem, thereby facilitating knowledge restructuring. This process represents a core characteristic of generative learning, namely organizing and reconstructing knowledge so that it can be effectively utilized in problem-solving contexts (Wittrock, 1994; Docktor & Mestre, 2014).

In the stage of executing the plan, a percentage of 25.00% was obtained, falling into the low category. Following the generative learning intervention, the ability to execute the solution plan demonstrated an increase to 76.67%, classified as the moderate category. The data indicate that each stage of problem-solving is interconnected; if students experience difficulties in the initial stages, it will consequently affect subsequent stages. As Leeuw, cited in Mustofa (2016), stated that problem-solving is a logical reasoning process (learning to think and reason) to resolve problems through continuous and interrelated stages. The execute the plan stage is associated with the application and reflection phase in the generative learning model. At this stage, students perform mathematical calculations, interpret the obtained results, and evaluate the alignment of the solution with the given physics concepts and conditions. Reflection on the solution outcomes enables students to assess the logical coherence and correctness of their answers, thereby reinforcing conceptual understanding and minimizing misconceptions. Thus, the integration of the generative learning model and Heller's problem-solving stages demonstrates that the application of generative learning directly supports the systematic and meaningful development of students' physics problem-solving abilities (Heller, Keith, & Anderson, 1992; Heller & Heller, 2010).

Table 3. Profile of Students' Problem-Solving Abilities After Intervention

Stage	Total Score	%	Category
Visualize The Problem	49	81.67%	High
Physics Description	49	81,67%	High
Plan A Solution	51	85.00%	High
Execute The Plan	46	76.67%	High
Average	48.75	81.25%	High

Table 3 summarizes students' problem-solving abilities following the implementation of the generative learning model. The profile of students' problem-solving abilities following the intervention indicated that the highest percentage was observed in the plan a solution stage, at 85%. This value was higher compared to the visualize the problem and physics description stages, each of which obtained percentages of 81.67%. This condition suggests that students tend to rely more heavily on their mastery and recall of formulas they have previously studied when solving problems. Furthermore, students are relatively infrequently trained to represent physics problems in the form of diagrams or graphs, resulting in the plan a solution stage being more dominant compared to the visualize the problem and physics description stages.

This finding is consistent with the research conducted by Hidayat et al. (2021), which reported that students' percentage scores in the plan a solution stage (62.8%) were higher than those in the physics description stage (51.3%) and the visualize the problem stage (45.2%). The findings of that study explain that students tend to be more proficient in planning solutions because they are accustomed to working on practice problems that require the selection and application of formulas. Nevertheless, they still encounter difficulties in visualizing problems into diagrammatic or graphical forms.

Similar findings were also reported in the study by Taufik and Wahyuni (2022), which showed that the average score for the plan a solution stage was the highest compared to the visualize the problem and physics description stages. The researchers revealed that students found it easier to plan problem solutions because they could directly select formulas available in textbooks or notes, whereas in the visualization stage, they still experienced difficulties due to their limited ability to represent problems in the form of diagrams or free-body diagrams.

Table 4. Frequency Distribution of Problem-Solving Abilities for Pretest and Posttest

Category	Score Range	Pretest		Posttest	
		f	%	f	%
Very High	81-100	0	0	6	50%
High	61-80	1	0,83%	4	33.33%
Moderate	41-60	2	16.67%	2	16.67%
Low	21-40	4	33.33%	0	0%
Very Low	0- 20	5	41.67%	0	0%

Students' problem-solving abilities prior to the implementation of the generative learning model obtained an average score of 32.50%, falling into the low category. However, following the generative learning intervention, the overall problem-solving abilities of students demonstrated an increase to 81.25%, classified as the high category. This improvement is also reflected in the frequency distribution presented in Table 4, in which most students shifted from the very low and low categories in the pretest to the high and very high categories in the posttest. This finding is supported by the research conducted by Ningsi (2023), entitled "Generative Learning Model in the Setting of Team Accelerated Instruction (TAI) in Terms of Students' Mathematical Problem-Solving Abilities," which revealed a difference in the average test scores of mathematical problem-solving abilities between the control class and the experimental class. The average score of the experimental class was higher than that of the control class, indicating that mathematical problem-solving abilities in the class implementing the generative learning model within the TAI setting were higher compared to the class employing direct instruction methods.

Based on constructivist learning theory, students are actively engaged in constructing their own knowledge, which aligns with the stages of the generative learning model namely, the challenge and application phases wherein students actively build their understanding through experimentation with PhET simulations and are provided with opportunities to solve varied problems. Consequently, students' problem-solving abilities improved following the implementation of the generative learning model.

These results serve as evidence supporting the assertion by Astuti (2006) that one of the constructivist-based learning models is the generative learning model proposed by Osborne & Wittrock (1985). As previously elaborated, the generative learning model places greater emphasis on efforts to activate students in constructing their own knowledge. The increase in the profile scores from before to after the implementation of the generative learning model illustrates that the essence of generative learning is that students do not passively receive information; rather, they actively construct an interpretation of the information, subsequently draw conclusions, and apply them.

Table 5. Normality Test

Variable	Kolmogorov–Smirnov Statistic	df	Sig.	Shapiro–Wilk Statistic	df	Sig.
Pretest	0.166	12	0.200*	0.91	12	0.211
Posttest	0.254	12	0.032	0.843	12	0.03

Table 6. Wilcoxon Signed-Rank Test Results

	N	Positive Rank	Ties	Negative Rank	P value
Pretest-Postest	12	12	0	0	.002

This study commenced with a normality test, the results of which are presented in Table 5. Based on the results of the preceding normality test, the posttest data were not normally distributed ($p = 0.030$); therefore, the non-parametric Wilcoxon Signed-Rank Test was selected to analyze the differences in problem-solving abilities between the pretest and posttest. The Wilcoxon test results, which are presented in Table 6, yielded a significance value (p) of 0.002, which is lower than the significance level of $\alpha = 0.05$. This indicates that there is a statistically significant difference between the pretest and posttest scores. Furthermore, the positive rank values indicated that all students exhibited an increase in scores from pretest to posttest, with no students experiencing a decrease or remaining unchanged. Consequently, it can be concluded that the implementation of the aforementioned learning model significantly improved students' problem-solving abilities.

The improvement in students' problem-solving abilities following the implementation of the generative learning model indicates that this model is capable of fostering a more meaningful learning process. Through generative learning, students—both individually and in group work—are able to construct and comprehensively comprehend the meaning of concepts, thereby enabling them to apply the learned material more optimally (Hakim, 2014). Moreover, the utilization of PhET simulations also contributed to enhancing students' problem-solving abilities. This finding is consistent with the results of Amanah (2023), which stated that the problem-solving abilities of students who employed a simulation-based learning model assisted by PhET simulations were superior to those of students who followed conventional instruction. Furthermore, the use of PhET has also been demonstrated to be effective in improving conceptual mastery and overall physics learning outcomes. PhET simulations can serve as an effective alternative virtual laboratory, particularly under conditions of limited infrastructure and facilities.

Table 7. Learning Effectiveness Based on Multiple Criteria

Effectiveness Criteria	Result	Description
Overall average N-Gain score	0.73	High category
Percentage of students with N-Gain > 0.3	100%	Target >75%
Significance test (pretest vs. posttest)	0.002	Significant if $p < 0.05$
Effectiveness conclusion	Effective	Effective/Not Effective

The effectiveness of the generative learning model assisted by e-modules and PhET simulations was evaluated using the N-Gain calculation. Based on the effectiveness criteria summarized in Table 7, the average N-Gain score obtained was 0.73, the percentage of students with an N-Gain above 0.3 reached 100%, and the pretest-posttest difference was statistically significant ($p = 0.002$). According to Hake's criteria, this value falls into the high category. This indicates that there was an improvement in students' abilities following the implementation of the applied learning model. Thus, the generative learning model assisted by e-modules and PhET simulations is considered effective in enhancing students' problem-solving abilities.

Table 8. N-Gain Effectiveness by Aspect

Aspect	N-Gain	Category	p-value
A	0.71	High	0.066
B	0.71	High	0.042
C	0.78	High	0.041
D	0.68	Moderate	0.042

The N-Gain effectiveness for each problem-solving aspect is presented in Table 8. The problem-solving abilities of students for each aspect based on Heller's stages include the ability to sketch the problem, describe the physical situation (including known and unknown variables), plan a solution, and execute the solution plan (Heller et al., 1992). The first stage, namely the ability to sketch the problem, obtained an average N-Gain score of 0.71, classified as high. The second stage, describing the known and unknown variables, obtained an average N-Gain score of 0.71, classified as high. The third stage, planning a solution, obtained an average N-Gain score of 0.78, classified as high. This finding is consistent with the generative learning theory, which emphasizes the process of integrating prior knowledge with new information through exploration and reflection activities (Osborne & Wittrock, 1983). In this context, PhET simulations serve as an interactive medium that enables students to test hypotheses, visualize abstract concepts, and predict outcomes prior to performing mathematical computations, thereby rendering the solution planning process more meaningful (Wieman et al., 2010). Meanwhile, the stage of executing the plan obtained an average N-Gain score of 0.68, classified as moderate. This result indicates that students' ability to review and evaluate the outcomes of their problem-solving still requires improvement. This condition is potentially influenced by several factors, including students' level of meticulousness during calculations and their capacity to interpret the final results obtained.

This finding is consistent with the research conducted by Sujanem (2022), which found that the use of problem-based physics e-modules for grade XI assisted by PhET simulations within an online PBL context was effective, as evidenced by a paired t-test result with a p-value of $p < 0.05$. It was therefore concluded that the implementation of problem-based physics e-modules assisted by PhET simulations can significantly improve students' critical thinking skills.

Study Limitation

This research was conducted in accordance with the procedures that had been designed. Although there was an improvement in students' problem-solving abilities based on the test results, these achievements were not yet optimal when compared to the findings of previous studies. Several limitations in this study are presumed to have influenced the outcomes of the ability development, namely:

1. The implementation of the instruction was carried out by the researcher rather than the subject teacher who typically teaches the class. This circumstance may have led to students being less serious during the learning process.
2. The scope of the research sample was limited, involving only 12 students; consequently, the findings regarding the improvement in problem-solving abilities cannot yet be generalized to represent the conditions of the broader population.

CONCLUSION

Based on the results and discussion presented above, it can be concluded that the implemented learning model is effective in improving students' problem-solving abilities. The N-Gain calculation yielded an average score of 0.73, which falls into the high category according to Hake's criteria. This indicates that the instructional intervention provided was highly effective in enhancing students' understanding and problem-solving skills on the straight-line motion topic.

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