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Research Article

GENERIC SCIENCE SKILLS: PHET APPLICATIONS BASED ON DISCOVERY LEARNING

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Abstract
This pioneering research embarks on an ambitious quest to assess the conceptual, procedural feasibility, and efficacy of a groundbreaking educational intervention, the Discovery Learning model teaching module infused with the innovative PhET application aimed at enhancing students' generic skills proficiency in the domain of chemistry. In a departure from conventional methodologies, this study employs a rigorous Research and Development (R&D) framework underpinned by the renowned 4-D Model to craft and validate this transformative pedagogical tool meticulously. The research cohort comprises high school students and chemistry educators poised at the vanguard of educational innovation. Employing a meticulously designed set of validation and response questionnaires, the study harnesses the power of descriptive and inferential statistics to glean profound insights into the impact of the intervention. The findings illuminate a resounding success: the Discovery Learning model teaching module, seamlessly integrated with the PhET application, exhibits exceptional validity and practicality and yields tangible improvements in students' generic chemistry science skills. Moreover, the overwhelmingly positive feedback from both educators and students, coupled with discernible disparities in responses between the experimental and control groups, underscores the transformative potential of this cutting-edge educational tool. This research's novelty lies in its pioneering development and validation of a PhET application-based Discovery Learning module, heralding a paradigm shift in secondary school chemistry education with the promise of fostering a new generation of scientifically literate and adept learners primed to navigate the complexities of the modern world.

Keywords: Chemistry, Discovery, PhET

INTRODUCTION

The implementation of the independent curriculum strengthens the principles of student-centered learning. This will have a positive impact on students to obtain the minimum abilities they must have, which are called generic skills, so that students are able to face competition in the 21st century (Deng et al., 2022; Ulenaers et al., 2021; Winda & Shofiardin, 2023). There are many generic skills that students must have (Asis et al., 2023; Lavi et al., 2021; Smiderle et al., 2020). One of the generic skills is problem solving skills (Dolce et al., 2020; Ginosyan et al., 2020; van Ravenswaaij et al., 2022). Problem solving ability is the ability to use thought processes to solve problems through collecting facts, analyzing information, compiling various alternative solutions, and choosing the most effective problem solution (Calavia et al., 2021; Simanjuntak et al., 2021; Virtanen & Tynjälä, 2019). Chemistry is one of the natural science subjects in high school that requires generic skills in its application (Astuti et al., 2020; Hu-Au & Okita, 2021; Setiana et al., 2021). Generic science skills are the ability to think and act in accordance with the scientific knowledge possessed, where these generic skills are closely related to scientific attitudes derived from general science process skills.

The results of interviews and observations of teachers and students at Negeri 5 Muaro Jambi high school show that learning is still teacher-centered. The teacher is more dominant in presenting the material, occasionally providing examples and practicing solving problems (Holmes & Tuomi, 2022; Mainali, 2021; Remillard et al., 2021). Practicums are rarely carried out due to limited facilities (Demirdag et al., 2020; Shaherani et al., 2022; Ekasari & Maulidinah, 2023). Interviews proved that some class XI students did not like chemistry lessons, this was because most had difficulty solving problems in the questions given. This fact certainly has an impact on low learning outcomes. It is thought that the low chemistry learning outcomes are caused by students' lack of ability to apply the concepts they have learned, which has an impact on generic science skills (Agustian et al., 2022; Musengimana et al., 2021; Wayan Santyasa et al., 2021). In detail, the cause of low generic science abilities is that teachers still tend to dominate the learning process (Yayuk et al., 2020; Lukman et al., 2021; Pawlicka et al., 2023; Buti & Ansyah, 2024). Students are only objects in learning activities and are not given the opportunity to discover for themselves the truth of the chemical concepts they are studying.

Some of the difficulties experienced by students in studying chemistry are due to the tendency not to know how to study, difficulty connecting between concepts, and requiring the ability to utilize logic, mathematics and language skills. This problem spurred researchers to find a solution by designing teaching modules for the discovery learning model (An et al., 2022; Othman et al., 2022; Zhong et al., 2022). Discovery is learning that occurs as a result of participants manipulating, structuring, and transforming information so that they discover new information (Javaid et al., 2022; Ngkoti, 2021; Weissler et al., 2021). Some of the benefits of Discovery Learning are that it creates a feeling of enjoyment, you will understand basic concepts and ideas better, you can utilize various learning resources (Hadi et al., 2020; Jarvis & Baloyi, 2020). Knowledge is long-lasting and easy to remember and trains students' cognitive skills to find and solve problems without the help of others.

Limited practicum facilities can be used as virtual laboratory media to make learning interesting, so that students' learning activities increase. The virtual laboratory-based learning media that is often used is the PhET application (Serevina & Kirana, 2021; Yakob et al., 2023; Andriani, Ramanayaka, & Bhatt, 2024). Simulation in PhET is a practical activity in a laboratory with interactive computer equipment (Endrayani et al., 2022; Ruwiyah et al., 2021; Sarwoto et al., 2020). The PhET application provides users with an in-depth understanding of concepts and can synchronize practical practical work, so that learning activities to improve generic science skills can increase (Boya-Lara et al., 2022; DeCoito & Estaiteyeh, 2022).

The Physics Education Technology (PhET) simulation is an interactive simulation on the internet, developed by Time from the University of Colorado, United States. PhET media emphasizes the connection of real-life phenomena with underlying science, supports interactive and constructivist approaches, provides feedback and provides a workplace. The advantage of this PhET application is that it can carry out experiments ideally, which cannot be done using real equipment (Drysdale et al., 2020).

In line with the results of previous research, the comparison between inadequate conventional laboratory conditions and discovery-based virtual laboratory learning is effective in improving students' science process skills. That the accessibility and availability of conventional laboratory facilities can be overcome through the implementation of virtual laboratory learning (Nirmala & Darmawati, 2021). However, previous research focused on improving students' science process skills. As a generalization of previous research, this research was carried out by developing a Discovery Learning model module based on the PhET application to improve students' generic skills abilities.

This research makes an important contribution in the educational context by emphasizing the application of the Independent Curriculum which strengthens the principles of learner-centered learning. The novelty of this research highlights the importance of generic skills in facing 21st century challenges, this research specifically highlights problem solving skills in secondary school chemistry learning. The low chemistry learning outcomes at Public High School 5 Muaro Jambi are largely caused by students' low ability to apply the concepts studied, resulting in low generic science skills. However, this research not only identifies problems, but also offers solutions by designing teaching modules with the Discovery Learning model and using PhET-based virtual learning media.

The implications are very significant, because it not only improves the quality of chemistry learning, but also encourages broader changes in learning paradigms and develops alternative learning resources that can overcome limited physical facilities in schools. Thus, this research not only has the potential to improve student learning outcomes, but also opens up opportunities for innovation in broader education through the application of technology in the learning process.

This research is urgent because it provides concrete solutions to improve the quality of chemistry learning at state high school 5 Muaro Jambi and overcome the low level of problem-solving skills, which are important in facing the challenges of the 21st century. With the Independent Curriculum approach which emphasizes student-centered learning, this research also encourages a paradigm shift in education. The use of PhET virtual learning media adds urgency to this research by providing a solution to overcome the limitations of practicum facilities in schools. Thus, this research not only has an impact on direct learning outcomes, but also on the broader transformation of education in line with the demands of the times. The aim of this research is to determine the conceptual, procedural feasibility and effectiveness of the Discovery Learning model teaching module based on the PhET application to improve students' generic skills abilities. And knowing the responses and differences in students' responses to the Discovery Learning model teaching module based on the PhET application to improve students' generic skills.

RESEARCH METHOD

This research adopts a development method, known as Research and Development (R&D), to develop and validate educational products. The model applied is the 4-D Model, which includes the Define, Design, Develop and Disseminate stages. The target of this research is upper middle class students who take chemistry science subjects at the school. The selection of research subjects was carried out using purposive sampling, where students were selected based on certain criteria in accordance with the research objectives (Lindfors et al., 2021; Simeon et al., 2022). These criteria include academic abilities and educational background in the field of chemical science. The number of respondents in this study was 60 students and 15 teachers. The strength of this research lies in the use of purposive sampling which allows the selection of research subjects according to certain criteria, thereby producing a sample that is homogeneous and relevant to the research objectives. Although the sample size is relatively small (60 students and 15 teachers), the use of appropriate sampling methods increases the validity of the research results.

This research procedure begins with establishing research objectives and a clear problem formulation. The next step is selecting research subjects using a purposive sampling technique, where subjects are selected based on certain criteria such as level of academic ability and educational background in the field of chemical science. After the subject is selected, a teaching module based on the Discovery Learning model using the PhET application is developed according to the stages in the Hannafin and Peck model. The development process involves creating a syllabus, Learning Implementation Plan, Student Worksheets, and relevant test instruments. The teaching module was then validated by three expert validators and three practitioner validators to assess its conceptual and procedural feasibility.

After the teaching module is validated, a trial is carried out on previously selected students. During the trial, data was collected through questionnaires, observations and interviews to evaluate the practicality of the teaching module and the implementation of learning. Next, the collected data is analyzed using appropriate data analysis techniques, such as descriptive and statistical analysis, to evaluate the effectiveness of the teaching module in improving students' generic chemical science skills. The results of data analysis will be interpreted to make conclusions based on research findings. The entire research process will be documented in a research report which includes a summary of results, interpretations, recommendations and suggestions for further research.

The data collection technique in this research is: giving a validation questionnaire to the validator to find out the feasibility of the teaching module. Provide response questionnaires to teachers and students to determine the practicality and effectiveness of the teaching modules being developed. Providing tests to students to determine the effectiveness of the teaching modules developed. The instrument grid in this research is presented in table 1.

Table 1. research instruments

Validation Questionnaire	Total items	Response Questionnaire for Teachers and Students	Total items
Clarity and completeness of the syllabus in the teaching module Suitability and relevance of learning program plans The effectiveness of student worksheets in teaching modules Effectiveness of test instruments in the module	10	Ease of using teaching modules Conformity to the curriculum and school needs The attractiveness and usefulness of the teaching module Clarity of explanations in teaching modules	16

The student and teacher response questionnaire instrument uses a 5 Likert scale. The categories for the student and teacher response questionnaire instrument are presented in table 2 below:

Table 2. Questionnaire categories of student and teacher responses

Category	Interval
Very not good	16 – 28.8
Not good	28.9 - 41.6
Enough	41.7 – 54.4
Good	54.5 - 67.2
Very good	67.3 - 80

Validation data analysis is analyzed using the equation:

$$\textbf{Validation} = \frac{\textit{The total score of the assessors}}{\textit{Maximum total score}} \, x \; 100\%$$

The average percentage uses the following equation:

$$\mathbf{X} = \frac{\textit{The total value of each validator}}{\textit{Number of Validators}} \, x \; 100\%$$

Eligibility criteria are determined based on Table 3.

Table 3. Instrument Validation Criteria

Validation Percentage Value Range (%)	Validation Level
0-20	Very invalid
21-40	Not valid
41-60	Fairly valid
61-80	Valid
81-100	Very valid

Agreement between validators is calculated using the percentage of agreement (PA) equation as follows:

$$\mathbf{PA} = 1 - \frac{A - B}{A + B} X \; 100\%$$

Information:
PA = precentage of agreemet
A = Frequency of assessment by experts who have high scores
B = Frequency of assessment by experts who have low scores

In accordance with the provisions that the teaching module is reliable if the percentage of agreement ≥ 75%. If less than 75% is produced, it must be tested for clarity and observer agreement. Analyzed to determine the average percentage with the following equation:

$$\mathbf{Mark} = \frac{\boldsymbol{The\ total\ score\ of\ the\ assessors}}{\boldsymbol{Maximum\ total\ score}} \boldsymbol{x}\ \mathbf{100\%}$$

The level of practicality of the instrument is determined based on the following table:

Table 4. Practicality Criteria

Percentage Value Range	Practicality Level
0-20	Very impractical
21-40	Not practical
41-60	Quite practical
61-80	Practical
81-100	Very practical

Analysis of the effectiveness of the teaching module is calculated using the N-gain test. The N-gain test is used to analyze generic science skills calculated by the following equation:

$$\boldsymbol{N - Gain} = \frac{\boldsymbol{Spost - Spre}}{\boldsymbol{Smak - Spre}} \boldsymbol{x}\ \mathbf{100\%}$$

With the following N-gain categories:

Table 5. N-gain Criteria

Interval	Criteria
$g > 70$	High
$30 \leq g \leq 70$	Moderate
$g < 30$	Low

The analysis continued with descriptive statistics and t tests assisted by IBM SPSS version 25 software. Descriptive statistical analysis used in research is intended to collect information about the situation at the time the research was conducted (Ambarwati et al., 2023; Samijo & Romadona, 2023). Before carrying out the t test, there were prerequisite tests that had to be carried out, namely data normality and homogeneity tests. The data to be tested must be normally distributed and homogeneous provided that the significance value obtained from the prerequisite test is normal and homogeneous > 0.05. By fulfilling the prerequisite tests, a t test can be carried out, namely the Independent sample t test, to determine the difference in student responses with the condition that the sig (2-tailed) value obtained is <0.05.

RESULTS AND DISCUSSION

Feasibility data consists of validation data and teaching module reliability data. The results of the validation of the teaching module were carried out by 3 expert validators and 3 practitioner validators.

Table 6. Results of Teaching Module Validity Analysis

Product	Mean	%	Category
Lesson plan	76.3	86.7	Very valid
Syllabus	35,4	89.4	Very valid
Test instrument	34,2	88.5	Very valid
Student worksheet	38,6	81.3	Valid
Phet media	27	83	Very valid

Table 7. Reliability of Teaching Module Validation Results

Teaching Module	Percentage of Agreement	Category
Syllabus	91.4 %	Reliable
Lesson plan	92.5 %	Reliable
Student worksheet	87.7 %	Reliable
Test Instrument	91.7 %	Reliable
PhET Media	89.4 %	Reliable

Based on Table 6 and Table 7, it is known that the syllabus, Learning Implementation Plan, test instruments and PhET Media are in the very valid category, and student worksheets are in the valid and reliable category.

Data on the practicality of teaching modules was obtained from teacher response questionnaires, student questionnaires, and learning implementation sheets.

Table 8. Results of Teacher Response Questionnaire Analysis

Teaching Module	Mean	Category
Syllabus	86.6%	Very Practical
Lesson plan	85.8 %	Very Practical
student worksheets	80 %	Very Practical
Test Instrument	81.5 %	Very Practical
PhET Media	82.7 %	Very Practical

Shows that the teaching modules developed are in the very practical category for syllabus, learning implementation plans, test instruments, PhET media in the very practical category and student worksheets in the practical category.

Table 9. Results of Teacher Response Questionnaire Analysis

Teaching Module	Mean	Category
How to Teach	77.5 %	Practical
student worksheets	77.3%	Practical
Test Instrument	77.5%	Practical

The practicality analysis results obtained for the learning process, student worksheets, test instruments are in the practical category. Data analysis of student response questionnaires

Table 10. Results of Learning Implementation Sheet Analysis

Meeting	Observer					
	1		2		3	
	Mean %	Criteria	Mean %	Criteria	Mean %	Criteria
I	93.2	Very Practical	92.5	Very Practical	89.2	Very Practical
II	93.9	Very Practical	93.4	Very Practical	87.2	Very Practical
III	88.5	Very Practical	92.1	Very Practical	86.2	Very Practical
Mean	91.87		92.67		87.53	
Criteria	Very Practical		Very Practical		Very Practical	

Based on table 10, the entire meeting from the observations of the three observers found that the teaching module was very practical to use in chemistry learning.

Table 11. Average analysis of Generic Science Chemistry skills via the N-Gain Test

X pretest	X Postest	N – Gain	Criteria
66	87	79	High

Based on the average N-gain test results for students' generic chemistry science skills, the N-gain score was 79 in the high category. So it can be said that teaching modules in the discovery learning model can improve students' generic chemistry science skills.

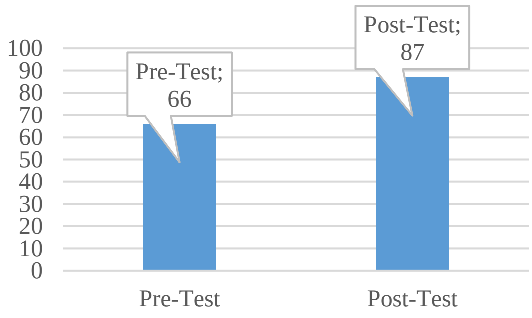

Figure 1. Graph of pre-test and post-test results of students' generic chemistry science skills

The description of the responses of teaching staff and students in using this teaching module is presented in table 10 below:

Table 12. description of the responses of teaching staff and students to the Discovery Learning model teaching module based on the PhET application

Respondent	Interval	F	%	Categories	Mean	Med	Min	Max
	16.0 – 28.8	0	0	Very not good				
	28.9 – 41.6	0	0	Not good				
Teacher	41.7 – 54.4	7	23.3	Enough	55.5	56.2	42.0	75.0
	54.5 – 67.2	7	23.3	Good				
	67.3 – 80.0	1	3.4	Very good				
	16.0 – 28.8	0	0	Very not good				
	28.9 – 41.6	0	0	Not good				
Learners	41.7 – 54.4	16	26.7	Enough	61.0	65.6	50.0	78.0
	54.5 – 67.2	40	66.7	Good				
	67.3 – 80.0	4	6.6	Very good				

Based on the results of the descriptive statistics above, it is known that the responses of teaching staff regarding the use of Discovery Learning model teaching modules based on the PhET application to improve students' generic skills are dominant in the fair and good categories. Then the students' responses to this teaching module were categorized as dominantly good with a percentage of 66.7% and an average of 61.0. Next, an independent sample t-test comparison test was carried out, before that the data was prerequisitely tested using normality and homogeneity tests. Following are the results of the normality test using Kolmogorov-Smirnov and homogeneity tests.

Table 13. Results of normality and homogeneity test data on student responses to learning using the Discovery Learning model teaching module based on the PhET application

Variable	Normality			Homogeneity		
	Sig	α	Note	Sig	α	Note
Student response	.200*	0.05	Normal	.187	0.05	Homogeneous

Based on table 13, it is known that the requirements for the comparison test are met, namely that the data is normally distributed, as seen from the significance value obtained, namely 0.200, more than the alpha value, namely 0.05. Then the data has the same or homogeneous variance, known from the significance value obtained, namely 0.187 more than the alpha value of 0.05. By fulfilling the requirements for the comparison test, we can continue with the independent sample t test hypothesis test.

Table 14. Independent sample t test results of student responses to learning using the Discovery Learning model teaching module based on the PhET application

Variable	Class	Sig. (2-tailed)
Response	X.A X.B	0.030

Based on the independent sample t test on student responses to learning using the Discovery Learning model teaching module based on the PhET application, it is known that there are differences in student responses between classes X.A and X.B. This can be seen from the sig value. (2-tailed) obtained is 0.030 less than the alpha value of 0.05.

The results of this research reveal that the Discovery Learning model teaching module based on the PhET application has succeeded in showing a high level of validity and practicality. Based on the analysis in Table 6 and Table 7, components such as the syllabus, learning implementation plan, test instruments, and PhET media are categorized as very valid, while student worksheets are also proven to be valid and reliable. Data on the practicality of the teaching module, obtained through teacher response questionnaires, student questionnaires, and learning implementation sheets, shows that this teaching module is very practical to use in the context of chemistry learning, including in the learning process, student worksheets, and test instruments. In addition, the results of the N-gain test show an increase in students' generic chemical science skills with an N-gain score of 79, which is categorized as high. Positive responses can also be seen from the description of the responses of teaching staff and students, which indicates that this teaching module can improve students' generic skills. The independent sample t-test comparison test shows that there are differences in student responses between classes X.A and X.B, which confirms that the use of this teaching module has a significant effect in the context of chemistry learning.

Previous research using a discovery teaching model assisted by PhET simulations found that there were significant differences in scientific literacy skills between female and male students. This research found that female and male students may have advantages in certain aspects of scientific literacy skills (Bahtiar et al., 2022). So as a form of novelty and generalization of previous research, this research was carried out by developing a Discovery Learning model teaching module based on the PhET application to improve students' generic abilities. The difference is that in previous research, student skills were analyzed based on gender based on the discovery teaching model assisted by PhET simulations.

The implications of this research show that the Discovery Learning teaching module using the PhET application can significantly improve students' generic chemical science skills, underscoring the need for further development in creating similar modules for other subjects. The use of technology in learning, especially PhET applications, opens up opportunities to increase student engagement and their understanding of science concepts (Ouahi et al., 2022; Rahmawati et al., 2022). In addition, the positive response from teaching staff emphasizes the need for teacher professional development, including further training to support the use of innovative approaches in learning. Another implication is the need for further research to deepen understanding of the effectiveness of various learning approaches and the factors that influence them. By paying attention to these implications, learning practices can be improved and students' learning experiences can be enriched in an era of education that continues to develop.

This research makes a significant contribution in the educational context, especially in chemistry learning (Hamzah et al., 2021). The novelty of this research lies in the use of the Discovery Learning model teaching module combined with the PhET application in improving students' generic chemistry science skills. This approach brings innovation by effectively utilizing technology in learning, thereby creating a more interactive and in-depth learning experience for students. Apart from that, this research also makes a contribution in the field of teaching module development, by showing that modules developed based on the Discovery Learning approach and using technology can be an effective tool in supporting classroom learning. The practical implications of this research create opportunities to enrich learning strategies in various subjects, as well as offering new insights into the application of technology in educational contexts. Thus, the novelty of this research lies not only in its empirical findings, but also in its conceptual contribution to the development of learning practices and the use of technology in education.

This research has several limitations. First, the generalization of the results is limited because it was carried out in several schools or classes. Second, limited data collection time may limit the observation of long-term effects. Third, research instruments may not fully cover all aspects that are intended to be investigated. Fourth, contextual factors such as student background or interactions between teachers and students cannot be fully controlled. Fifth, the limited sample size affects the representation of the results. For further research, it is recommended to conduct a longitudinal study that pays attention to the long-term effects of using Discovery Learning-based teaching modules in chemistry learning. Testing with more stringent controls is also needed to ensure the observed effects are caused by the intervention under study. Comparative studies between different chemistry learning approaches, as well as a focus on different student populations, would also provide valuable insights. In addition, research on the technical aspects of teaching modules and the influence of teacher training on their use also needs to be explored further. Through this approach, further research can deepen understanding of the use of Discovery Learning-based teaching modules in improving chemistry learning. For further research, it is recommended to conduct a longitudinal study that pays attention to the long-term effects of using Discovery Learning-based teaching modules in chemistry learning.

CONCLUSION

From the results of this research, it can be concluded that the Discovery Learning model teaching module based on the PhET application has been successfully developed, shows a high level of validity and practicality, and is able to improve students' generic chemistry science skills. In addition, the positive response from teaching staff and students as well as significant differences in student responses between the two groups indicate that the use of this teaching module has the potential to increase the effectiveness of chemistry learning. For further research, it is recommended to conduct a longitudinal study that pays attention to the long-term effects of using Discovery Learning-based teaching modules in chemistry learning.

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AUTHOR CONTRIBUTIONS

Conceptualization, Haryanto and Aulia Sanova; Writing, Original Draft Preparation, Methodology, Atri Widowati and Adhe Saputra; Software, Formal Analysis, Writing & Editing.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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